What Lies Above: Using Poetic Methods to Interrogate User Positions Across GNSS Infrastructures

by

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For all the satellites

Abstract

This thesis argues for the use of what I term 'poetic methods' in approaching the study of Global Navigation Satellite Systems (GNSS) infrastructures. Poetic methods frame research experiments with techniques drawn from art practice and build understandings of an infrastructure's actions, or the "texture" [1] of those actions by leveraging symbol and metaphor.

This work is situated in an interdisciplinary space across Human Computer Interaction (HCI), art, design and the study of Science, Technology and Society (STS). The theoretical grounding of the work draws on Actor Network Theory (ANT) and Karen Barad' s intra-activity [2] to emphasise sociotechnical practices and objects as emergent across combinations of material agency.

From Bowker and Star's concept of infrastructural inversion [1], I argue that infrastructures become visible through points of breakdown. To probe GNSS infrastructure, I stage an experiment where its smooth operation is disrupted. Re-framing the infrastructure in this way draws participant's attention to its influence in forming practices. I then use a second method of short form speculative design [3] workshops to have participants think about scenarios where the user is pushed further into the background and user and infrastructure are understood as nodes in 'more-than-human-networks'.

Alongside this participant-facing research work, I give an account of artworks that developed from my own practice in response to the research questions. These are understood as deep responses to the design workshops' prompt to re-think how we understand the actions, influence and ontology of GNSS infrastructures.

At the end of this art and research process I have a finished artwork and several sets of rich qualitative data. I use these to understand how effective my techniques are in

achieving infrastructural inversion, diagnostically understanding the actions of GNSS infrastructure and the texture of how those actions are felt by participants, and interrogating ontological questions around concepts of 'user' and 'infrastructure'.

I argue that the poetic methods offer an innovative set of techniques that can be added to a wider research project to help interrogate blackboxing, practically achieve infrastructural inversion and begin to move towards ontological critique. These offer a new methodological tool to STS researchers and contribute to HCI debates around non-user-centered design practices. I offer some suggestions for further refinements to these techniques and point towards some possible future work.

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Chapter 1

Prologue

"It's putting another space onto another space onto another space." - *Dial Stories* participant

Dial Stories was an early project in the development of the research described here. I used participatory workshops to explore how use of the FM spectrum can re-frame a sense of place through broadcasting site-specific creative writing. The project argued that locative technologies 'perform' space, working through the texture of their often hidden actions. The actions of large infrastructures are often not easy to understand as discreet. Rather, through their reach and support of other technical systems, they are experienced as texture, a set of actions which can be felt through their grain and rhythm rather than through contained and falsifiable effects. Bowker and Star argue that metaphor is a useful way to understand these textures [1].

In the case of *Dial Stories*, a sense of texture was provided by the participants' creative writing. Participants were asked to write a sensory and experiential response to the physical site. The writing was spoken (by the participants), recorded, then placed on a series of short range FM transmitters which were distributed around Mile End Park in east London. Via transmission, the writing traveled around the site and became entangled with other threads in the blanket of radio signals that lies over the city, while

also being deflected by buildings and trees at ground level. At the end of the workshop, the participants walked together around the park, using small FM receivers to listen, dropping in and out of the stories they had contributed and finding what else was waiting to be heard in the electromagnetic realm (see figures 1.1 and 1.2).

Figure 1.1: Participants listen to their radios in Mile End Park, London.

Figure 1.2: Participants move through the park, using their movement to retune between signals.

The idea of poetics is strong here, not only in terms of the creative writing, but also in the elements of complexity, chance and surprise in how the participants were able to tune into the transmissions containing their words. The project lead to a thickening of the experience of place, in one participants' words; "putting another space onto another space onto another space." As their voices became small and fragile within the broader electromagnetic spectrum, participants described finding a "pocket" of signal against "a wall of other stations or static". At the same time, moving their bodies subtly from one direction to another could lead to a pan across the spectrum that saw signals dropping in and out. Bringing awareness to the texture of interactions between radio, body and site points to an understanding of space that is richer, more complex and full of possibilities for interpretation.

By including the Dial Stories project at the start this thesis I begin my argument for the use of what I call 'poetic' techniques to tease out the "texture" of an infrastructure's actions [1]. In the thesis 'poetic methods' refers to a commitment to staging experiments in ways influenced by the artistic practices of myself and others. Such work can create a sense of defamiliarisation from commonly used technologies and, thereby, achieve an infrastructural inversion [1] that makes the texture of the infrastructure more discernible. I suggest that this shift in attention, emphasising metaphor and performativity as descriptive tools, is an original and rewarding way of approaching locative technologies and their accompanying infrastructures. The metaphors that participants create in response to the experiments described in this thesis can act to create rich alternative understandings of the ways technologies and their supporting infrastructures act as part of wider causal networks. In addition to achieving a diagnostic process for participants, such an approach shifts the way they understand familiar technologies and can, it is intended, also play a critical and pedagogic role.

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[1] G. Bowker and S. L. Star, *Sorting Things Out: Classification and Its Consequences.* Cambridge, MA: MIT Press, 1999.

Chapter 2

Introduction

Over the past 10 years locative technologies enabled by Global Navigation Satellite Systems (GNSS) have become extremely influential in the way we orient ourselves in space. This influence can range from simple navigation to a variety of supported spatial practices. When arriving in a new city we can cache a local map on our smartphones and use the device's GNSS sensor to orient ourselves. At the other end of the scale, cases of 'Death by GPS' are known to have happened when a driver or hiker has unquestioningly followed a device's directions into remote or dangerous places [1]. The practices supported by GNSS are diverse and include dating, social media and exercise tracking. These practices, as well as supporting users' tasks, provide a rich fabric of positional data which can be gleaned from software, re-packaged and sold. The combination of locative technologies and emerging practices has, therefore, been transformative, changing the possibilities of both what individuals can do in and with their location and what can be done with their location data.

It is also worth noting that GNSS has dramatically shifted wider 'infrastructual' practices which are not user-facing. GNSS sensors are ubiquitous in the navigation of land and sea freight as well as passenger vehicles from airplanes to private cars. The timecodes generated by GNSS satellites' on-board atomic clocks are used to syncronise

high frequency financial trades across borders. The technology also has extensive military applications. It was first developed in the United States in the 1970s as a means to target missiles more precisely. Nowadays its use in military contexts is widespread [2], while the military implications of the ground infrastructure is also considerable, with antennas and control stations housed in military installations around the world. Besides this, GNSS has a variety of environmental uses: It produces extremely accurate positional data of tectonic plates that can help in earthquake prediction; NASA's CYGNSS project uses the same technology to measure wind speeds and ocean surface roughness in an effort to forecast hurricanes. In this way it echoes the description Jennifer Gabrys draws from a 1999 *Business Week* article which suggests the planet will soon don an "electronic skin" [3] (p. 6) of sensors producing millions of data points. While GNSS is certainly implicated in this vision for a ubiquitous computing end point, it remains its own technology with its own origins, affordances, agencies and effects.

The most commonly known GNSS is the Global Positioning System (GPS). This American system was the first to be launched and the first to achieve full global coverage with a constellation of 32 satellites currently occupying a carefully choreographed pattern of orbits that allows at least four satellites to be visible anywhere at any time. In 2011 the Russian constellation, GLObal Navigation Satellite System (GLONASS) also achieved global coverage, while the Chinese Beidou system is, at the time of writing, very close behind. Smaller systems, providing more local coverage also exist operated by India, Japan and the European Union. In this way it can be understood as a technology which is strongly embedded in political and economic contexts through both development and use.

GNSS reception involves complex interactions with surrounding environmental contexts. A GNSS sensor works by comparing timestamps in satellite signals. Signals may reflect off buildings creating time delays which can throw off a location fix, or the speed at which a signal travels through the air may be altered by humidity levels. These technical and political complexities are, however, rarely noticed by people as they use

location based software on their smartphones in their everyday practices. Our everyday experiences of GNSS are primarily user facing and, as such, they follow a well-worn design logic of concentrating on the task at hand rather than the tool which performs the task [4].

As a result, people become illiterate to the infrastructural complexities surrounding the political and technical operation of GNSS. As users, they are written into the roles prepared for them by designers and technical infrastructures (although some points of negotiation are available in practices of use and refusal always remains an option). In this thesis, I am interested in developing methods to rethink the experience and practices of using these technologies. I argue that what I call 'poetic methods', which borrow from artistic practice, are particularly well positioned to rethink the presence and effects of GNSS infrastructure. They can offer new understandings of GNSS infrastructure both as a system in itself, and in how it can be understood within a wider network of attendant contexts, interactions, causes and effects. The drive towards re-thinking our relationship to the ways technology intersects with our everyday experience speaks to a wider question of critical awareness.

Often, the realities created by technologies that shift peoples' practices become sites for new methods of control. The well documented influence of directed news and advertising in social media, especially during elections, are strong recent examples [5, 6]. In the case of GNSS, the practices being re-negotiated by technology concern the ways in which we navigate space. In this thesis I argue that, through GNSS, spaces emerge through a combination of actions and interactions between manifestations of 'user' and 'infrastructure'. What is at stake here, therefore, is less about specific strategies of critical awareness and resistance (although these do emerge in the data) and more about identifying underlying ontological conditions which facilitate how this shift in spatial practices takes place and what the act of re-thinking it does to how 'users', 'designers' and 'infrastructures' are manifested.

This work can be understood as a theoretical and ontological investigation into GNSS

systems, motivated by the desire to re-think present practices. I argue that, when practices and figures like 'user' and 'infrastructure' become fixed, their workings become solidified and concealed in a blackbox [7] which concentrates power in one dynamic. What I aim for through this work is a splintering of narratives to create a new spread of potential and emerging practices and ontologies. In practical terms, through an intersection with discussions of method, this process can offer a thickening of research data, making it richer and more complex.

As an interdisciplinary artist and researcher, I argue that this work can make contributions to researchers looking to catalyse reflection in their participants and designers aiming to foster a critical spirit in their own projects or as part of a wider participatory process. At the same time, the work finds resonance in artistic contexts. A chapter of the thesis is given over to a discussion of art works that have emerged from this research. These works are motivated by the same questions as the more consciously research-facing outcomes. Through this process, art and research can be understood to deepen and re-enforce each other.

2.1 Orientation

In disciplinary terms, I work at the intersection of art and science. In this PhD project I am oriented in an interdisciplinary space crossing Human Computer Interaction (HCI), Science, Technology and Society (STS) and Design. My orientation in and contribution to these fields takes place across theoretical and practical considerations.

Art practice has had lengthy and productive intersections with each of these fields. In HCI and design, it has found resonance with researchers and designers working with artists to produce objects or interaction systems (in the field of locative media art, the collaboration between The University of Nottingham's Mixed Reality Lab and artist group Blast Theory [8, 9] provides strong examples). There has also been considerable discussion in HCI about the potential for critical design (and design with a critical focus)

and where it exists in relation to artistic practice [10, 11].

In STS, art practice has offered potential for space to exploring new ideas and theories. In his curatorial notes for the *Making Things Public: The Atmospheres of Democracy* exhibition at ZKM Karlsruhe, Bruno Latour argued that art and curatorial practices have the power to exist outside the disciplinary requirements of academic structures, acting as exploratory thought experiments [12]. Salter, Burri and Dumit offer a detailed description of the ways they feel that art practice can feed into STS research: As a means to explore the production of science through aesthetic experiences; As a way to develop methodological techniques; As an extension of public-facing science communication; and to question and critique the political formations of existing practices [13] (p. 140). In this project, I take inspiration from Salter et al's interest in art practice's intersection with alternative methodological techniques and to question and critique the political formations of existing practices.

I also draw on Latour's argument that thought experiments are less beholden to disciplinary concerns. This is particularly important in interdisciplinary work such as this. One sub-motivation for this project is to bring some of the theoretical work done in STS, into HCI, giving the critical work that happens there a stronger theoretical as well as practice-led dimension. HCI and design work can often be grounded in a particular problem area or the development of a solution. My intention is that, by mixing these disciplinary concerns through the lens of art-influenced method, I can bring more theoretical concerns to HCI, particularly in questioning the ontological limits and interactions between concepts such as user, infrastructure and interaction. To do this, I borrow from STS, building on ontologies that emphasise co-productive objecthood and agency [14–17] to see these concepts as emerging and relational constructions. This is done by building research experiences that question our existing understandings and practices around GNSS technology, thereby asking research participants to pay a deeper attention to the infrastructure itself.

In this way, my position is consciously artistic and directed to what has been under-

stood as a more 'avant-garde' set of values. At the same time, it seeks to make these values engaged and critical in regard to existing practices through the use of participatory workshops. The process-driven workshops are intended to catalyse participant reflection through conceptual development rather than produce a finished or usable object or service. This is design which is motived by research aims, following Daniel Fallman and Matt Ratto as positing 'design-oriented-research' as separate from 'research-oriented design' [18, 19]. As I will argue in the literature review and discussion chapters, a balance between engaged and theoretical concerns is important for navigating current debates about the applicability of more critical and expansive approaches to HCI.

2.2 Poetic Methods

The tools I use to question understandings and practices around GNSS draw from my own artistic work. My background is primarily as an artist working with participatory practices. I am interested in work which can create alternative imaginaries through installations and short-form collaborative processes. Much of my technical background is in sonic arts. A previous participatory project grounded in these influences is described in the thesis prologue. *Dial Stories*, a collectively authored FM radio space project involved the recording and transmission of site-specific creative writing. Through this trajectory in my artistic work, I am interested in how spaces are processed, modified and represented by technologies and combinations of technology and human participant. Alongside this work I have produced interactive sound installations, experimental radio works and multichannel sound performances.

In this PhD project, inspired by the history of locative media art, I explore how GNSS currently performs a similar act of spatial processing; changing the way we engage with the world around us through combinations of machine and human understandings. As I dug deeper into this subject I began to realise how influential GNSS infrastructure was in defining the terms of these understandings. I also realised how little the workings of that

infrastructure were widely known. My interest went from exploring how infrastructure was forming imaginaries around space to wanting to see how these imaginaries could be made thicker and more complex, in the process not just rethinking spatial practices, but also ideas of human user and technical infrastructure themselves.

My motivation in using human participants was born out of interests in collective authorship (and research data as collective authorship) and critical pedagogy. The methods developed in this thesis act partly to probe the operation of imaginaries around GNSS to satisfy my research questions, but also aim to create a poetic, thought-provoking and rewarding experience for participants. While this later point alludes to the potential art practices hold for critical pedagogy. While it does not do this in a strict or formal sense, by challenging practices and shifting understandings, it is intended to add some value for participants as well as simply using them as a source of data.

The 'poetic' techniques that I describe in the thesis draw on two ideas derived from my art practice: the importance of staging in setting up a research experiment and the power of metaphor to access the often obscure workings of a blackboxed infrastructure. First, in terms of staging, I created research experiments that sought to re-frame existing sociotechnical practices around GNSS. In one experiment I asked participants to walk around the Barbican, a housing estate and art gallery in London where, due to the monolithic architecture, GNSS was notoriously unreliable. As they walked they used a smartphone app that gave them diagnostic information about GNSS signals and the presence of satellites. The exercise was, therefore, designed as a way to elegantly invert the typical behaviour one performs when using GNSS. Rather than walking around looking at a phone trying to find out where they are, the exercise asked participants to walk around looking at their phone trying to find out where the infrastructure is. The participants' familiar behaviour therefore became a metaphor or conceptual bridge [20] through which they could understand how the infrastructure operates.

Metaphor and fiction are key to my understanding of poetics. In the second research study described in this thesis, I asked participants to respond to a speculative design

brief that offered them a fictional, near future world. They were asked to think of an object, service or scenario that could exist in this future world. Here the idea of poetics is more direct through the way it incorporates narrative. The participants were offered a fictional world and encouraged to produce fiction in response. Poetics leverages the power of narrative and metaphor to re-describe and, thereby, re-think familiar practices and ontologies.

In their writing on infrastructural inversion, a process by which a concealed or black-boxed infrastructure are revealed, Bowker and Star suggest that an infrastructure, although hidden, can be felt through the "texture" [21] of its actions. Infrastructures often support other technical systems or practices and therefore these actions may well be indirect, making it a slippery thing to grasp. Keller Easterling describes the "disposition" (a concept similar to Bowker and Star's texture) of an infrastructure's actions as "not the pattern printed on the fabric, but the way the fabric floats... Not the object form, but the active form." [22] (p. 21). Bowker and Star suggest that, because of this indirectness, metaphor is a powerful means of describing infrastructural action [21].

In my own understanding of poetics, therefore, metaphor does not only play a powerful role in the staging of research projects, but also in the means through which to elicit and understand data. In the walking workshops, I encouraged participants to do free writing and drawing to tease out their responses before joining a group discussion. The imagery and metaphor produced in this work formed the basis of my analysis. Likewise, in the design workshops, participants were asked to create a fictional object or scenario. Given such a free reign they fastened onto particular metaphors which can be understood diagnostically as drawing attention to particular textures of the infrastructure, providing information about how the infrastructure's actions are felt and, in turn, how concepts such as user or infrastructure emerge.

2.3 Research Questions

To explore the relationship between user and infrastructure in GNSS I set myself two research questions in three parts:

1. How can poetics and metaphor be used as research methods for getting at the 'texture' of blackboxed infrastructures?

2. Does this way of shifting attention towards infrastructure:

    - Change understandings around the centrality of the user and user experience?

    - Change understandings about the nature of more-than-human networks?

My theoretical starting point for the first question is that complementary concepts of blackboxing [7] and design inscription [23, 24] work to conceal the operation of GNSS infrastructure. Through a design focus on the task at hand [4, 25], infrastructural tools become conceptually sealed. From here it is difficult for 'users', as constructed by these processes, to see how GNSS infrastructure at large is acting, or to think through alternatives.

To find a way to unpack the infrastructure and its actions, I turn to Star and Ruhleder's work on theorising infrastructure [26] and Bowker and Star's work on unpacking it through a process of "infrastructural inversion" [21, 27, 28]. They outline several features of infrastructure which can be leveraged to create an inversion, making its presence and functionality more visible. One of these involves drawing attention to moments of infrastructural breakdown.

To draw attention to these moments of breakdown, I use a walking method, drawing on poetic staging and an attention to infrastructural texture as understood through metaphor. Here, I have groups of participants walk around sites in which the physical architecture challenges a device's ability to establish a GNSS fix. They can track the device's efforts using an open source app called *GPS Test* (developed by Chartcross [29])

which reverse-engineers the usual flow of information through a GNSS sensor to produce a visualisation of how many satellites are overhead, their positions, and their signal-to-noise ratios. In other words, the app shows how GNSS infrastructure is operating in relation to a device's position. By having participants conduct the experiment in architecturally challenging locations, it becomes possible to see moments of breakdown as GNSS operates under stress. Using this framing as a prompt, I ask participants to reflect on their everyday practices around GNSS and to consider how an increased awareness of the infrastructure's texture may cause these practices to shift.

The second question explores how this shift in attention towards infrastructures and their textures may shift the ontological relations through which conceptual objects such as user and infrastructure emerge. Ontology is here understood as pertaining to the nature of being, raising questions about the indivisibility of these objects. Part of the critique of blackboxing is that it congeals and solidifies a set of dynamic and emergent relations into what appears to be a coherent object [7]. This coherence comes at the expense of a nuanced understanding of how both the infrastructure and surrounding objects emerge through complex and conditional interactions. Typically, we see the infrastructure as an object, rather than what Star and Ruhleder understand as a series of actions [26]. Therefore, while the first research question asks us to critique the hidden nature of the infrastructure and its effects on our practices, these questions ask us to go further. They ask us to consider the attendant ontologies that give rise to commonly held sociotechnical practices around GNSS.

In the first part of this question I see if and how my methods can shift a focus on the figure of a user and their experience. The user has been a focal point for design practice for many years. Some of the most influential work in this field coming from Mark Weiser. In the early 1990s he argued that interaction should be driven by the task at hand [25] and the tool used to achieve that task should be intuitive to the point of invisibility [4]. While such approaches may achieve frictionless interaction experiences, the success of this approach may also render it hegemonic, meaning that designers do

not work with alternative aims or measures of success. Akrich's concept of inscription [23] proposes that design, in addition to creating the kinds of task which are achievable, can also create different kinds of user, shaping the kinds of interaction or understanding which are both permitted by the system and, as these tasks become implicit and internalised, possible to imagine for the system user. This research question, therefore, asks whether poetic methods can work to re-frame the powerful and influential figure of the 'user' away from something that is understood as narrowly task-driven and rather more ontologically fluid, with the potential for different interactions and understandings in relation to infrastructure.

The second sub-question asks if a similar shift can be achieved in relation to what I call more-than-human networks. Again, this question refers to a process by which participants are asked to shift their ontological understandings of user and infrastructure. Here, more-than-human networks are understood as the emergent network of actions and interactions that allow relations to form into objects. The more-than-human formation takes in infrastructures, technical systems, their protocols and conventions of practice. The use of 'more-than' is significant because it asks us, not to eliminate the human user, but rather to re-orientate it as one node within a larger emergent system. In this system, the different materialities and rhythms of the human and the non-human will rub with and against each other, causing friction and synthesis and, thereby, creating other textures which can be understood through the use of poetics and metaphor. The research question asks if poetic methods can achieve this kind of shift in understanding and, if so, how they can tease out these different textures and transformations.

Practically speaking, this second question with its two sub parts will be addressed primarily through the design workshops which propose alternative fictional scenarios. The use of speculative fictions here allows existing ontologies to be re-organised into new forms. These alternative understandings are conveyed primarily through metaphor as participants work with possible scenarios within this fictional world. The metaphors are primarily intended to explore the present world rather than offer attainable new designs.

By offering a rich space for metaphorical exploration, the work seeks to tease out the textures of the hidden ontology forming processes that lead to monolithic concepts such as user and infrastructure, re-framing them as nodes within expanded more-than-human networks.

2.4 Structure of the thesis

The thesis is organised into seven chapters, with chapter 1 being an account of my previous artistic work and this introduction forming chapter 2.

Chapter 3 is a review of the existing literature. Because of the interdisciplinary nature of the project, this review addresses the work through several different frameworks of theory and technique. I begin with a brief review of locative media art, highlighting some key projects from 1999 to the present day. I am concerned with the ways in which these projects act performatively to create space and spatial interactions. In this review, I address some notable projects which use location specific semantic content (images, audio, text), but am particularly interested in projects that engage with the technical tools that facilitate locative media art. I choose to place my work in this tradition as an artist and researcher. Building on the idea of performativity in locative media, I introduce blackboxing and inscription, some concepts from STS that discuss how infrastructure and designed objects act productively to define practices and positionality for the 'user'. I describe some ethnographic approaches which, as methods, intersect with STS-influenced work as ways of tracking sociotechnical practices and using that data to form theory. I also describe some specific critical design approaches, discussing how they have been deployed in HCI and what potential they also hold to critique and de-stabilise established practices and positionalities. The thrust of this thesis is to use poetic methods to critique and destabilise established practices and ontologies. I use this chapter to describe some existing methods from which I take inspiration and identify some ways in which my methods can deepen research around blackboxed infrastructures

and ontologies.

Chapter 4 details the poetic methods I have developed to address my research questions. I begin the chapter by proposing an understanding of method that emphasises the transience and fragility of research and argues that, in response to such fragility, it is necessary to develop methods which are case-specific and introduce answerability to research questions [30]. Answerability is here understood as an ability to address the research questions. At the same time, I acknowledge that methods must be open to the rich contexts which surround them and, in acknowledging those contexts, aim to "enrich and not only reduce" the object of study [31]. My approach engages with hidden discourses around GNSS infrastructure, which, through blackboxing and inscription, are not in the forefront of participants' practices. To address these issues I developed and iterated methods which could firstly use poetics to activate infrastructural inversion to unpick blackboxing and, secondly, allow shifts in ontological understandings of users, infrastructures and how they fit in wider more-than-human actor networks. These techniques provide a sense of the infrastructure's texture in terms of sociotechnical practices and ontology. In keeping with my understanding of method, these needed skillful poetic staging to address the ontologically obscure requirements of my research questions. To analyse the research data, I chose situational analysis [32, 33] as a technique which was broad enough to incorporate my own heavily designed research staging and the contextual factors which I intended to incorporate and contribute to.

In chapter 5 I describe the experiments, using my two methods, and present the findings. These take the form of a series of situational analyses built from themes extracted from the data. These analyses are presented as research narratives built from meta-themes that describe what was happening in each experiment and how the methods engage with my research questions. To accurately represent what was an iterative and shifting process the chapter goes into considerable detail. This detail is also intended to introduce accountability into the analyses which I form. Analysis of the first method forms an arc that highlights three stages: alienation; environment and dynam-

ics. These refer to participants' alienation from their usual sociotechnical practices, a growing awareness of a new environment composed of the influence of GNSS signals, and the dynamics which are at play within that environment. These 'dynamics' refer to the critique and repositioning of established sociotechnical practices around GNSS. In my analysis of the second method, a series of speculative design workshops, I describe the symbolic frameworks that participants built to engage with a future scenario. Building from these structures, I describe several themes which participants used to re-draw the boundaries between human user and satellite infrastructure. These are: control over human populations and resistance; satellites as a benign power or guardian angel; GNSS as a tool which continues to serve human goals; and satellites which exhibit behaviour learned from human practices. These themes should be understood diagnostically as ways of reading present understandings of user and infrastructural ontology. The metaphors which emerge again provide useful lenses through which to view infrastructural texture.

In chapter 6 I describe some artistic outputs which have emerged alongside this work. These works represent outcomes of my theoretical positioning, research interests and artistic practice. They can be viewed as my own artistic response to the research questions and the call to offer re-understandings of infrastructural emergence, ontology and corresponding sociotechnical practices. I describe the use of the walking workshop technique on the *Made of Walking* and *Sound Development City* residencies. I also describe a developed artistic work, *GPS Tarot*, which proposes conducting tarot readings based on the position of GNSS satellites. In these readings, the cards are laid out in a spread that corresponds to satellite positions. For this project, I drew on comparisons between satellites and stars. Historically, stars were also used for navigation and orientation and took on a dual role of storytelling and divination. The project suggests such a dual role for GNSS satellites. *GPS Tarot* has been presented at the DIS conference, Edinburgh and FACT, Liverpool, as well as distributed through *GPS Tarot* business cards which have led to hundreds of remote readings.

In chapter 7 I discuss my research findings. I outline the ways my work responds to

Salter et al's call for artworks to feed into STS research through methodology, critical pedagogy and aesthetic work. I then discuss how successfully poetic methods were able to address my research questions. To do this I draw on themes built on the metaphors produced by my experiments. I conclude that the methods were successful in addressing the first question and I describe some of the implications of this success. While they were largely successful in addressing the more ontologically focussed second question, they also threw up larger issues about how far human participants can de-centre themselves to become part of more-than-human networks. I go on to outline the innovations these techniques offer, in particular as a means to access obscure and hidden research objects such as blackboxed infrastructures. I argue that poetic methods offer the potential for transferable tactics to produce richer research data in methods that work with ontologically obscure subject matter. I conclude this chapter with some further reflections on the next stage of development for the techniques.

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Chapter 3

Literature Review

3.1 Introduction and Structure

In this chapter I give an overview of the theoretical approaches I draw on in this work. Much of the theoretical work described here comes from STS. My aim in using this literature is to interrogate how infrastructures and users intersect and are produced through GNSS-driven sociotechnical practices. I situate this theorisation through the lenses of art, design and ethnography.

In the first section of this chapter I give a brief history of locative media art. This work is relevant for situating my own practice between art, design and HCI and provides understandings of how GNSS infrastructure can be performative, producing spaces, experiences, tasks and users. Much of the early work in this field concentrated on the addition of semantic content (images, text, audio) to locations, but another strand engages with the influence of the infrastructure in creating interactions. I give particular attention to the latter.

Building on this attention to infrastructure, I begin the next section by providing a detailed description of the history and development of GNSS infrastructure. I then

use two key concepts from Actor Network Theory (ANT); 'blackboxing' [1, 2] and 'inscription' [3–5] to describe how this infrastructure becomes tacit and invisible in user practices. I focus in particular on the extent to which, following widely-held design principles, designers direct users to concentrate on the task at hand rather than the technical tool.

In the following section I draw from the cross-disciplinary approaches of infrastructure studies [6–12] to theorise how an infrastructure can be described and what it does within the world. I suggest Bowker and Star's "infrastructural inversion" approach [8] as one with considerable potential to challenge the present tacit, blackboxed nature of GNSS infrastructure. Infrastructural inversion offers a critical and theoretical route to fight against infrastructure's tendency to disappear through processes such as blackboxing and inscription. In so doing, we can theorise more richly on the productive role infrastructures play in the emergence of sociotechnical practices.

Star and Ruhleder [6] argue that infrastructure does not have a bare form, but is rather understood by its actions. In this it finds an echo in the understanding of performativity proposed in relation to locative media art. The processes through which users and infrastructures emerge across these actions require further explanation and I turn to Karen Barad's work on intra-activity to explore this. For Barad [13, 14], a key point is that actions cause the formation of 'users' and 'infrastructures'. Neither of these are pre-existing causal agents. Such work can challenge the way in which research has traditionally been conducted. In order to understand how such theory can be applied I give an overview of STS-driven ethnographic approaches which use sociomateriality to collect and analyse data in order to understand the co-productive role of organisational structures and technical apparatuses.

Much of the work operating within this theoretical paradigm aims to be critically engaged as well as descriptive [15–17]. I share this aim and, in order to move towards it, I turn to critical and speculative design. In a similar way to many locative media art practices, this approach asks us to shift our focus in the way we use objects and

technologies. Although such design projects are as varied as the artworks described below, typically they work to make us rethink the context of the objects, taking attention away from discreet use cases and toward the wider sociotechnical context. They also share an urge to shift away from user centered design approach, to a more authorly mode [18]. In this way they hold common ground with artistic practice as individually productive enterprise (though many critical and speculative designers would resist the description of their work as art [19]).

Critical design has taken many forms and tactical applications in HCI where some debate exists around these techniques' form, application and usefulness. I cover this debate in brief, following Pierce et al [18] in arguing for the tactical application of different 'critical design' manifestations depending on research context. In my work here, I concentrate on one technique in particular; speculative design. I argue that this approach, in the way it proposes future worlds and alternative realities, allows us to radically critique and rethink our established user-centered practices. Importantly, in a break from Dunne and Raby's proposal for Speculative Design [20], my methods offer a space for exploration rather than working towards a finished design object. In this they are influenced by Matt Ratto's critical making technique [21]. By creating a space in which to critique user-centered practices I am not responding to a discreet problem, but rather trying to engineer a wider shift in which the boundaries between user and infrastructure can be questioned through an ongoing process leveraging poetics and metaphor. Speculative design is well versed in such shifts through the way it addresses wicked problems [22, 23]. Wicked problems contain shifting contexts and requirements and are therefore difficult to pin down. Such problems may require a re-interpretation of the entire problem space rather than a discreet solution [20].

The theoretical tools described in this chapter are diverse and cross several disciplines. To make the relationship between these tools clearer, I make the following statements about how GNSS infrastructure is understood in this thesis:

GNSS Infrastructure:

- is explored through the disciplines of HCI, STS, Locative Media Art and Design.
- is understood as an active force in ways that are not always obvious because of blackboxing and inscription,
- is understood through a wider theoretical framework informed by material agency and intra-action. This agency means GNSS infrastructure performs and produces spaces, users and practices.
- will be critiqued using poetic methods built on infrastructural inversion and speculative design with the aim of describing the texture of the infrastructure's action and ontology.

3.1.1 Poetic Methods and the Literature Review

In the introductory chapter, I described poetics as a guiding force in this thesis. I understand poetics as a process of re-describing the world, using metaphor as a means to cast existing processes in a new light or to change the way they are understood to act, especially in relation to surrounding contextual processes. In this literature review I pass through several frameworks which intersect with the re-framing of familiar objects using art practice, metaphor or fiction.

I contextualise poetic methods through each stage of the literature review. My initial survey of locative media art points to annotative practices that seek to thicken the experience of place and more critical projects which create or uncover the complex influence technical artefacts have on our everyday lives. In my review of infrastructural inversion I note that Bowker and Star point to metaphor as a useful way of describing and understanding the texture of infrastructures as they act, bending the world around themselves in both large and small ways [8]. In my review of ethnography and STS I describe Haraway's concept of 'double vision' which urges scholars to both understand practices in a diagnostic sense and point to ways we might speculate about alternative

configurations and theorisations [24]. In the final section I argue that speculative design is a promising way to achieve such a double vision. Speculation can work in a diagnostic sense, telling us more about the world as it is by offering alternative futures, and, in so doing, point out a diagnosis of the present situation and paths that we might follow to imagine alternatives. The combination of this multi-disciplinary literature frames my own methodology which uses metaphor and poetics in both staging research and generating understandings of hidden and tacit infrastructures.

3.2 Locative Media Art: A Review

Locative media art offers a point of practical and theoretical intersection between HCI, art and design. In practical terms, this area has seen project-based collaborations between artists, researchers and designers [25–27] while other figures such as Jen Southern and Mark Shepard have straddled the boundaries between these disciplines and approaches, working within STS and design respectively. In theoretical terms, performativity has acted as a common thread through projects. Performativity is here understood as the idea that both specific media art projects and locative media at large perform and, thereby, produce spaces through their operation. This theoretical thread has been consistently in place since the early days of locative media art theorisation [28, 29] and also resonates strongly with more recent theoretical approaches which emphasise the entanglement of humans and technology [13, 30].

I see my own work as operating within this theoretical and practical tradition. In the work detailed in this thesis I aim to deepen the theoretical application of performativity through a focus on the productive power of GNSS infrastructure. I develop this idea of performativity through the rest of this chapter, first by looking for the seams where the infrastructure's practical and conceptual operation begin to break down. I approach this initially through methods which emphasise moments of breakdown and alienation from usual sociotechnical practices. I build on this, offering fictional worlds in which to situate

GNSS where the infrastructure takes a noticeably more active role in the production of agency and, thereby the boundaries which delineate space, user-ship and infrastructure.

In this section, I will give a theoretical review concerning the ways in which locative media art projects can be considered performative. I will then describe several types of project and how they engage with this theory. These projects provide examples of the intersection between HCI, art and design and give a context of work for my own project. Although the categories are fluid, for ease of reading, I have broken them down into three broad areas: Annotative projects (concerned with adding semantic content to locations); Mapping projects (concerned with recording mobility across space); and Critical projects (concerned with critiquing the ways we typically interact with locative technology and space). Projects across these three areas shift in their interrogation of human users, infrastructural aspects and spatial resonances, occasionally muddying separation of the three. Such steps are in keeping with an understanding of performativity which suggests that fixed categories emerge from the actions which take place in locative media art, rather than causing them.

3.2.1 Performativity

Performativity has a varied set of applications, from linguistic performativity [31] to broader, social understandings [32]. I take performativity around location as a kind of doing; manifesting a set of social, cultural or economic contexts [33], while, at the same time, staying conscious of method that "both performs itself and is performative of researcher and researched" [34].

To understand this 'performativity' in the sense of 'doing' location it is useful to return to consider the early theory around locative media art. The term 'locative media' was coined by curator and designer Karlis Kalnins at the Art + Communication Festival in Riga, Latvia in 2003 [29]. The construction of the locative case in Latvian and Finnish is somewhat different from English, corresponding to the prepositions 'in', 'on',

'at' and 'by'. It declares a final location or time of an action [28, 29, 35–37]. This is a subtle but extremely important distinction because it carries the understanding that location is not a static point, but rather the performance of an action. Location is something (or somewhere) we *do* rather than something we are static *in*. In the projects described below, location is also being made to act. By becoming a site of storytelling, annotation or interaction, it becomes a dynamic element in a placemaking process, rather than a static point on a map. Performativity, understood in this way, has also proved influential for social scientists working on locative media and attempting to understand the interactions locative media leverages and the spaces it creates [38, 39].

Largely situated within communications studies, theoretical scholarship refers to locative media variously as a "field of cultural production" [29]; a "site", "framework" and "context" [40]; and a "philosophy" [41]. In keeping with the popular uses of locative media for social media and gaming, much recent work focusses on locative media as a socially-driven "field of cultural production", particularly through its relationship to more traditional understandings of space. The idea of hybridity or 'hybrid space' is particularly influential. Communications scholar Adrianna de Souza e Silva [42] describes it as "merg[ing] the physical and the digital in a social environment created by the mobility of users connected via mobile technology devices" (p.264). Historically, this approach marks a reaction to early criticisms of mobile technology which claimed it led to users becoming disengaged from the world around them, "Conversely, [mobile devices] strengthen users connections to the space they inhabit, because the connection to other users depends on their relative position in space" [42] (p.270). Such work is often rooted in ethnographic studies of users' experiences of locative media, including location-based social networks [38, 43, 44] and location-based mobile games [45, 46].

A focus on the practices undertaken in hybrid spaces reinforces Kalnins's original conception of location as something which is performed, rather than a static point. In Gordon and de Souza e Silva's conception of "net localities", [47] "the radical visibility of located data creates the *potentiality* for users to experience meaningful nearness to things

and people [emphasis in original]" (p. 12 – 13). This potentiality is key in defining the relationship between location and its uses. The bare information of location offers a nail on which to hang meaning formed through action. In the resulting net localities, the meaning formed by locative media practices is primarily social, tied up with interactions between people. Here the activation of hybrid spaces through the performance of location is squarely driven by the user and the, primarily social, interactions they engage in.

Performativity need not, however, be restricted to the actions of a user. We might also consider the influence of other agents involved with the production of location. In particular, it is useful to think about the "material agency" [13] of the objects and infrastructures involved. Such an approach argues that non-human elements have the potential to shape the performance of location as much as human users. Indeed, the theorist Karen Barad argues that, through a relationship of "entanglement", the fixity with which we understand users, spaces and infrastructures emerges through their interaction, rather than as a precursor to it. In a similar way to Kalnins's understanding, location is an action rather than a place, the actors and places involved emerge as a result of this action rather than existing as pre-existing causes of the action. This more radical understanding of performativity will emerge strongly through my own work and can be seen to a varying extents in the projects described here.

3.2.2 Annotative Practices

The first project area I'd like to draw attention to is annotative projects. These are among the earliest examples of locative media art and typically involve adding semantic content to specific latitude-longitude points. Several of these projects involve adding sonic content. These practices are particularly effective at creating hybridity of space through the way they allow a person's senses to be split between sight, smell and touch on one hand, and an alternate heard space on the other. Such projects therefore use their performativity to create new spaces by re-drawing the boundaries between sense experience and the meaning of a site.

Many of these projects use equipment which pre-dates our familiar, smartphone-driven tools for using GNSS. An early art project, *Trace* (1999) by Teri Rueb, provided the participant with a backpack containing a GNSS sensor and audio playback system. Appropriately attired, they would hike around Yoho National Park in the Canadian Rocky Mountains, hearing personal stories connected to the theme of loss which were triggered by their position. The project was thematically integrated within the local environment, with the hike taking place through a Burgess shale fossil bed. By using an environment full of traces of former ecosystems and imbued with death, decomposition and memory, Rueb was able to parallels with the theme of loss that ran through the recordings.

Attaching audio content to location continued to be a popular tactic for artists in the following years. The *34 North 118 West* project was authored by Jeff Knowlton, Naomi Spellman and Jeremy Hight in 2003. It added location-specific audio to a square mile around downtown Los Angeles. As participants moved around they triggered stories about the history of the site performed by voice actors. This project is framed as an artwork, but could arguably also sit comfortably as oral history or audio walk. Both these projects work with ideas of annotating space, either adding personal narratives or uncovering narratives which are already present and less visible. The act of uncovering is a strong theme in some theoretical work around locative media art, particularly through designers Ward and Galloway's comparison between locative media and archeology [35].

Other projects brought interactivity to the idea of annotating space. Mark Shepherd's *Tactical Sound Garden* (2006) and the *[murmur]* project (2003 to present) allow users to add their own content to a site. The first iterations of *Tactical Sound Garden* used a contained Wi-Fi field as a metaphor for a garden, encouraging participants to place or 'plant' sounds for others to find with wireless headphones. This work is a more traditional installation, taking place in a discreet site. Later iterations took the project out into the wilds of public space. *[murmur]* took on a wider scope. Beginning in Toronto, then iterated around the world, *[murmur]*'s system allows people to phone in

a story related to a particular location. It aims to provide a platform for the "intimate, neighbourhood-level voices that tell the day-to-day stories that make up a city" [48]. We can see one difference here in the overlap of the elements within the system. Shepard's project offers the ability to place sounds in relation to other sounds already present, thereby giving the potential for social overlap and collaborative conversation. On the other hand, *[murmur]*'s focus is primarily on the relationship between participant and site. It is a kind of mapping practice, again deeply connected with ideas of documenting experience through oral history.

Urban Tapestries (2002-4), another notable project from the same period, frames itself as a "transdisciplinary research" project [49] which allows people to add text, pictures and audio to sites in central London. This type of multimodal annotation is now common in apps such as *Yikyak* and *Yelp*, while *Facebook*, *Instagram* and *Twitter* all support geo-tagging of content. The influence of another proposal from the same group; 'geo-jogging', can also be seen today through numerous apps which track the route and speed of a jog or run. These projects provide an early iteration of locative media design which would become commonplace with the mass adoption of smartphone-based locative technology. They also begin to open up theoretical avenues through which to understand the importance of multiple contexts in approaching site, particularly the hybridity of social interactions via a digital overlay.

Within a HCI tradition, early experiments with locative media typically centred around the questions they raise for the design of user experiences, particularly around designing for 'hybrid' spaces. The long term collaboration between artists' group Blast Theory and the Mixed Reality HCI Lab at the University of Nottingham provides a good example of this. Blast Theory's work is often hosted by galleries and museums and frequently takes place in public space. Participants interact with each other within (often ludic [50]) experiences overlaid on top of the 'real' world. Notable examples include *Can You See Me Now* (2001), a locative chase game played in city streets, which won the Golden Nica award at Ars Electronica 2003 and *Rider Spoke* (2007) where participants

cycle around the city using locations determined by Wi-Fi access points to 'hide' recorded messages for others to find. Papers produced by Blast Theory and the Mixed Reality Lab focus on the ways in which the design of interactive experiences can be informed by locative media art projects, while also calling for interdisciplinary interaction between computer science, performance and theatre research and practice [25]. They note that a major challenge to the design of such work is the complexity of the situation in which the experience takes place. Participants are confronted with "hybrid structures" of space, time, participant roles and interfaces. Within such a structure the designer can provide "interactional trajectories" which are steered by participants, but shaped by the affordances of the system [51].

This more fluid understanding of annotative works dovetails with theories of performativity. The spaces in question are being produced by a performance of interactions between the system (through its affordances) and the actions of the player. In this case, it is a small jump to understand the affordances of the system as, themselves, holding material agency. The organisation of the system influences what kind of spaces are performed by the player even as the player may work against the affordances set by the system, creating new ones. This pushing back against system affordances has been theorised elsewhere as inscription [3] and translation [4] and is discussed in more detail later in this chapter.

3.2.3 Mapping Practices

Another strong trend in locative media art involves using GNSS to map the movement of people and objects. Esther Polak's 2002 *Amsterdam Realtime* project (with Jeroen Kee and Waag Society) used a mass of participants to map peoples' movements with GNSS tracking devices. Participants were asked to navigate the city according to a set of proscribed instructions or their own whims. Such 'mapping' techniques have proved popular. Prominent art and design examples include Wilfred HuJeBek's Transmediale prize-winning *dot.walk* (2002), Christian Nold's *BioMapping* (2004 – present) and Carlo

Ratti / MIT senseABLE City Lab's *Real Time Rome* (2006).

These projects take us away from the idea of locative media encountered by the individual, and lead us to think about the same media encountered by the many. They shift attention from discreet individual encounters to a quantitative understanding of the sociotechnical practices across a mass of people. In this way, they can be understood as a precursor for practices of data mining and analysis around mobility. Consider Transport for London (TfL), the umbrella organisation which maintains much of London's public transport infrastructure. Analysis of the movements of a mass of people form much of their day to day work. The technology here is electronic touch cards rather than GNSS sensors, but the outcome is similar to the projects described above. TfL constantly map and analyse such real time data to make their services more efficient. Such data also provides ample material for visualisation and many examples can be seen through the work done at University College London's Centre for Advanced Spatial Analysis (CASA) [52, 53]. These visualisations can be highly influential in terms of policy and, in the case of TfL's visualisation practices, go on to define how the city's transport infrastructure is run. In this sense they are deeply performative in that they have the potential to produce influential political and economic relations between citizens and work and leisure places. They also serve to create different kinds of citizen and worker, such as the figure of the commuter, tuned to the vagaries of a specific tube or bus line.

Another notable project by Esther Polak took a slightly different tone. *MILK* (2003-5, with Ieva Auzina) used GNSS to follow the production and shipping of milk from a dairy farm in Latvia to a cheese factory in the Netherlands, depicting its journey through a series of installations. Here the focus of the mapping is on a 'thing', rather than a user. MILK uses GNSS to make processes of production within the food industry visible, providing a critique, but also allowing us to see how a familiar commodity changes form as it moves across national borders and through industrial processes. For media theorists Tuters and Vanelis [37], the force of the work is that it exposes "the actions of global trade, thereby making visible the networked society" (p. 362). In the process, it uses

GNSS to point to the ways that different territories perform matter, by processing it into different forms for different modes of local consumption.

A focus on mobilities has also guided Jen Southern, whose recent work also focuses on the mobility of the non-human. In *Searcher* (2015), a mountain rescue dog and its handler were equipped with a GPS tracker and a GoPro camera during a simulated rescue. Images from the GoPro cameras were then placed on kites, whose flying explores the interactions and mobilities performed by the combination of dog, handler and (for the kite) wind. Another project by Southern, *Polyrhythmia* (2013) uses six whirring and tapping machines as instruments which respond to the movement of participants as tracked by GPS as they move around the city. The work builds on Henri Lefebvre's idea of the city as composed of a series of overlapping rhythms [54]. Here, rather than understanding GPS as a user interacting with their environment, the city is understood as a totality produced through the performance of individual movements.

3.2.4 Critical Practices

While several of the projects mentioned above seek to play with our usual sociotechnical practices to create new experiences, there is a strain of locative media art project that calls for a stronger focus on the role of technical infrastructures in the performance of location. Here I concentrate on these projects, and especially on the focus they place on the "material agency" [13] of infrastructure. This agency is understood as a performance of location through collaboration between the human and the material, technical or infrastructural base of a technology.

One example of this kind of intersection is Mark Shepard's *Hertzian Rain* (2009). In this project, participants wear wireless headphones which are streaming sound. They also carry umbrellas coated in foil that deflect electromagnetic signals. Through the reflective properties of these umbrellas, the ability of the participants to hear the sonic transmission is constantly being altered by both their position and the positions of the

other participants. In another layer of complexity, the position of the participants is recorded by the system and the wireless transmission is adjusted in turn to progressively reveal and obscure the quality of the transmission. This excess of parameters creates what sociologist and media theorist Federica Timeto has called "unpredictable feedback loops" [39] within the system. In this way, the participants, objects and connections all play an active role in modifying, creating and altering the experience of the installation. The act of hearing the sound in headphones is just one point of meaning within the system, rather than the crucial one. Interactive installations are usually understood as being user-centered, with participants responding to a set of parameters that provide some sort of experience. Here the situation is reversed: users are merely another 'object' within a network of objects (material and immaterial) that interact, bounce off and connect with each other. Such a project also draws on a de-centered ANT-influenced idea of networks. Each actant (transmitter, umbrella, headphones, participant, software) within the system is constantly co-creating the others. In Shepard's project therefore, rather than acting as independent objects, each of these elements has a profound effect on the other; the umbrellas change the effects of the transmitter, the software acts in response to the movements of the participants. No object is able to act in isolation, rather, each is constantly emerging through the action of the other parts of the system.

In *Hertzian Rain*, Shepard constructs his system to leverage stress and breakdown as key points in which meaning emerges. A focus on breakdown and inaccuracy also provides the starting point for artist Nikki Pugh's ongoing *Colony* project (2011 to present). One artwork in this project; *Landscape Reactive Sashes* (2012-2013) [26], has participants walk with two GPS-enabled devices, comparing the position each one provides. The participants also wear a sash containing a transducer which vibrates at different rates depending on the level of discrepancy between the positions provided by the two devices. The project works to make the tools involved in providing a location fix profoundly visible. It also brings them into a relationship with the surrounding environment, as participants move around, it becomes clear what types of physical environment allow

GPS networks to function well and which create inaccuracies. This shows that "rather than functioning as an abstract grid superimposed on the landscape, GPS is affected by the materiality of the spaces we move through" [55] (p. 166) and thereby makes another, physical aspect of the infrastructure visible. In a similar early experiment, *You Are Here: Information Drift* (1994), architect Laura Kurgan fixed a GPS receiver to the roof of the Storefront for Art and Architecture in New York. Perhaps due in part to the selective availability built in to civilian GPS devices at the time, the receiver was unable to establish a consistent location fix. Writing in the exhibition catalogue, Kurgan noted that "much of the building disappears within [the receivers] margin of error", leading Geoff Manaugh to reflect that "Kurgan had discovered a kind of ghost architecture, a parallel city made from moving buildings and spectral property lines" [56].

Pugh and Kurgan's work points to a focus on breakdown which provides a useful way to identify and interrogate the action of technical infrastructures [8]. However, in addition to the critical leverage these techniques provide, in an artistic sense, we can begin to appreciate the presence and poetry of GNSS infrastructure through those moments of stress of breakdown. Following Barad [14], these moments make clear the "entanglement" and "intra-action" between human and non-human agencies in GNSS.

Similar concerns are addressed in artist Julian Oliver's *Border Bumping* (2012). Oliver's project, part of his 'Critical Engineering' approach, documents the seams which emerge at national borders as a cellphone attempts to lock onto different service providers. Video and printout information about the uncertainties and bumps created at these sites are presented as a gallery installation. This work examines another aspect of the network which is particularly open to breakdown, thereby challenging the idea of the digital communication realm as an evenly spread overlay on the non-digital world. Political borders and economic asymmetries matter in the way such a realm is produced both for users and for the software which supports cell and smartphones.

Design work can also offer a critical route into locative media. In his *Sentient City Survival Guide*, Mark Shepard offers a series of speculative designs for a "near future

sentient city" (characterised by the approaching 'smart city'), equipped with ubiquitous computing which is "capable of reflexively monitoring our behavior within it and becoming an active agent in the organization of our daily lives" [57]. One project, *Serendipitor* (2011) plots a navigation route based not around speed or destination, but around the potential of getting lost and stumbling upon new aspects of the city. The origins of this idea can be seen in the situationist concept of the derive; the directionless walk taken by the flaneur (walker without direction) which made the city seem strange and unfamiliar [58]. As well as acting as an art project, developed and cited in artistic contexts (the V2 Institute for Unstable Media in Rotterdam and Eyebeam in New York), a project like this can be also called critical design in that it seeks, through authorly qualities, to shift design discourses away from user-centered design [18, 19]. Critical design is a powerful and contentious term within HCI and a detailed debate around this term and its deployment is given later in this chapter.

3.3 GNSS

Before describing the ways in which infrastructure is theorised and its (often hidden) influence interrogated, it is instructive to give a brief technical and historical overview of GNSS infrastructure. GNSS multilateration is the most pervasive means of establishing a location fix in use today. Most of us are familiar with its use in mobile devices and dashboard navigation devices. It supports the socio-technical practices of location specific social media and also influences emerging economic relations through on-demand transport services such as *Uber*. Such relations are contentious and evolving. Recent years have seen multiple protests against apps such as *Uber* by taxi drivers in cities across Europe. Beyond mass user-facing applications, GNSS has also had a wide-ranging influence, transforming logistics fields such as container shipping, helping pilot aeroplanes or changing our relationship with lost pets, prisoners and pensioners through tagging.

The oldest and most famous GNSS is the American Global Positioning System (GPS).

GPS emerged from research funded by the Pentagon in the 1970s, with an initial ten satellites launched in the period up to 1985. Currently the GPS network comprises a constellation of 31 satellites, positioned in six orbital planes. A minimum of 24 are required to provide 95 percent coverage of the earth's surface and the system can maintain a maximum of 33. The GPS network also comprises a series of ground stations which are responsible for updating an almanac of satellite positions (used by devices to cross reference satellites and establish location) and make small adjustments to satellite orbits or on-board atomic clocks. The whole system is maintained by the US air force and found much of its early use in military operations. Indeed, it is said that, during the first Gulf War, Saddam Hussein mounted GPS jammers on the roof of his palaces to throw off the targeting of any incoming missiles [59]. During the same conflict the military recalibrated satellite orbits to ensure greater coverage of the Middle East and temporarily deactivated the 'selective availability' restrictions put on non-military accuracy so invading American soldiers could guide themselves using civilian devices sent from home by their families [60]. The ground portion of the GPS infrastructure is dotted around the world at US air force complexes in: Yorkshire, UK; Diego Garcia (Indian Ocean); Guam (Pacific Ocean) and other locations which host military personnel as a result of treaties or a history of conquest. I mention these details to emphasise that a system which may appear to be odourless and value neutral when represented by a blue dot on an iPhone map, is in fact a highly complex infrastructure developed and maintained by a military organisation. In this way, GPS is deeply implicated in US military power and the politics of the deployment of that power around the world. Its continuing functionality depends on the continuing functionality of US military hegemony.

The US is, however, not the only state with a GNSS. Other systems exist, born from and maintained by specific political and economic contexts. The Russian GLObal NAvigation Satellite System (GLONASS) system took longer to develop to its present capacity, development started in 1976 with the constellation being completed in 1995. The capacity of the constellation fell in the late 90s before funding was dramatically

increased in the early 2000s. The system had achieved 100 percent coverage of Russian territory by 2010 and 95 percent global coverage by 2011. The slower pace of the deployment of the GLONASS system also points to ways in which locative infrastructures are intimately tied to events on the earth. Political and economic shocks in Russia during the period in which the technology was being developed and deployed influenced the system's construction and maintenance, and thereby its ability to function for both civilian and military functions. Since then, many sensors in mobile devices have started to use both the GPS and GLONASS systems. By having more usable satellites in view at any one time, a GNSS sensor can establish a location fix more quickly and accurately.

At the time of writing (mid 2018), the Chinese BeiDou GNSS (formerly known as COMPASS and named for the Chinese word for the big dipper constellation) is regionally operational. This means that, while it does not yet quite have enough satellites in orbit to produce global coverage (23 out of 24 required), its orbits can be synced to allow for complete regional coverage for civilian and military purposes. For most civilian uses, the satellites which are in view in any given place can play an auxiliary role to the GPS and GLONASS systems, allowing for increased accuracy. The European Galileo system is currently some way behind with 11 satellites launched. The system is planned to have an extended constellation of 30 satellites (24 active and 6 spares) by 2020, though its development to date has been beset by political and economic delays and technical issues. The Indian NAVigation with Indian Constellation (NAVIC, which is also the Sanskrit word for sailor or navigator) system works in a different way from GPS, GLONASS, BeiDou and Galileo. It uses three satellites in geostationary orbit and four in geosynchronous orbit. Because of this organization, it has no pretensions to be a global system, but is instead focused on the Indian sub-continent where it is used for civilian and military purposes. It is said that the development of NAVIC was driven by a moment in the Kargil conflict with Pakistan in 1999. At this time, the American military refused to share relevant GPS information with India [61] leading to the construction of an Indian system with a specific regional remit.

In addition to the political, economic and military contexts in which GNSS systems operate, there are a series of environmental factors which can disrupt and enhance their function. Every satellite is constantly emitting electromagnetic signals (with different bands reserved for civilian or military operations). Each signal has a timestamp embedded in it by the satellite's on-board clock. The sensors in mobile devices need to be able to establish a line of sight with at least four satellites to provide a location fix. The fix is established by comparing the timestamp within each signal with an almanac contained in the device. This almanac a record of the orbits of each satellite. By comparing the time differentials in satellite signals, the sensor can establish a position. However, like other electromagnetic signals, GNSS signals move through air at slightly different rates because of factors such as humidity. The system contains corrective algorithms to mitigate against the inaccuracy that this may cause, but nevertheless, this feature exposes the GNSS network as something profoundly physical. Indeed, this aspect of the infrastructure has been leveraged by weather forecasting companies to give an accurate reading of air humidity levels [59].

A physical factor which is more noticeable to the average user is the need for lines of sight to be established with multiple satellites to provide an accurate fix. For this reason, a GNSS fix is difficult to establish when the user is indoors (although, this is often mitigated in software by referring back to the last available fix). The user is also likely to feel this aspect of the system when moving around a city with narrow streets (such as Venice or Dubrovnik) where the reduced amount of sky visible at street level makes multiple lines of sight difficult to establish. A device's GNSS sensor and the way it is integrated into software may also affect the speed and accuracy of a location fix. These environmental factors serve to emphasise that, as explored in Nikki Pugh's *Colony* works, the locations produced by GNSS are not universal, flat or even, but rather in a state of constant flux and negotiation with a breadth of other factors.

3.4 Infrastructure

3.4.1 Blackboxing

Despite the complexity and multiple uses of GNSS systems, our experience of them is highly limited. We rarely encounter them directly, our point of reference is often a flashing, blue 'you-are-here' dot on a map application. Applications such as *Tinder* and *Uber* push the infrastructure further into the background, leaving the user to concentrate on the activity or practice at hand. Existing software also mitigates against any breakdown in this system being noticed; Android and iOS developers can specify that the class associated with location works with the best available fix from surrounding Wi-Fi hotspots, GSM triangulation or a combination of these with GNSS. As such we can understand GNSS infrastructure as being concealed or, to use a term from Actor-Network Theory (ANT) discourses, blackboxed. In the following sections discussing blackboxing and inscription all the scholars come from an STS background unless otherwise indicated.

For Latour [2], blackboxing is understood as the way in which "scientific and technical work is made invisible by its own success" (p. 304). In the same way that the use of a device like a refrigerator might become so widespread that we cannot imagine life without it, information infrastructures have the potential to "become tacit in thought and action for human users" [62]. As Geoffrey Bowker argues, when such developments become tacit, they gain an aura of inevitability, as if their development could not have taken any other course [7]. Blackboxing can also be understood as a fundamentally asymmetrical process. Callon and Latour argue that it allows a micro-actor to become a macro-actor, which "bends space around itself, makes other elements dependent upon itself and translates [its] will into a language of its own" with a greater degree of success [1] (p. 286). The crux of this power lies in invisibility; many actors become understood as one object or system and it becomes more difficult to imagine how things could have developed a different way. As Mol notes, this process has implications for the way our surroundings are understood, both in spatial and political terms [63].

The process of blackboxing in GNSS has a special resonance in the political role played by the macro-actors who design, deploy and operate GNSS systems. When we think of GPS, GLONASS, Beidou or NAVIC, the political and military aspects of its use are rarely foregrounded. While the dual role GNSS play in civilian uses and military operations may be the most obvious example of this, it is also worth considering the systems' territorial requirements. In order to successfully maintain an operational satellite constellation, ground antennas and control stations are needed at numerous points on the earth's surface. For GPS, these intersect with the presence of the US military in places as far apart as the South Pacific, the Indian Ocean and the South Atlantic. As such, GPS is allowed to operate successfully because American soldiers, sailors and pilots are permanently stationed around the world. For GLONASS, the majority of ground stations are based within former Soviet territory (the exception being a station in central Brazil), but this comes with its own attendant contexts of Russian expansion across the North and Central Asian continent. As GNSS becomes an increasingly widely used system, essential for multiple industries as well as individual users, more elements become reliant on a small number of states having a permanent military presence around the world. This renders GNSS infrastructure profoundly political. The invisibility of satellites with the naked eye and the often secluded nature of the ground infrastructure has led media theorist Lisa Parks [12] to argue that "publics around the world have both been excluded from and/or remained silent within important discussions about their ongoing development and use" (p. 207).

As Callon and Latour describe, building dependence is a key aspect of the power relations which form alongside blackboxing. In addition to the uses described above, a large economy exists around the recording, plotting, packaging and re-selling of personal location data, and while GNSS is not the only source of this data, it acts as an important means through which this data is generated. In these ways, as a macro-actor, GNSS infrastructures begin to shape the world around them creating economic and political dependencies. Individual users may also feel this process in their daily practices. GNSS

has become an important way to orient oneself within an unfamiliar environment, profoundly affecting our idea of what is and isn't possible spatially. Again, this process can be particularly successful because of the invisibility that blackboxing affords. In losing awareness of the blackboxed system, combined with its widespread adoption, it becomes difficult to imagine how we could continue to live and work without it.

3.4.2 Design Inscriptions

Blackboxing may ultimately be realised by the proliferation of a particular infrastructure, but is also the result of a series of inscriptions from designers. Akrich notes that the affordances of a system or object work to try and define which tasks are possible, which in turn defines the nature of the user [3]. The complexity of this process has been emphasised in empirical studies of inscription [5, 64, 65]. In my analysis of GNSS systems, there is considerable overlap between blackboxing and inscription, particularly because many design inscriptions work to make the infrastructure invisible.

The theory of inscription emerged in part in reaction to Social Construction of Technology (SCOT) approaches which argued that human action shapes technology [66]. These approaches were themselves a reaction against earlier technological determinist models (for a detailed account of these developments see Oudshoorn and Pinch [67]). However, inscription should not be seen simply as reactionary. In Akrich's words:

> "We cannot be satisfied methodologically with the designers's or user's point of view alone. Instead we have to go back and forth continually between the designer and the user, between the designers projected users and the real users, between the world inscribed in the object and the world described by its displacement." [3] (p. 209).

A key aspect of inscription is that, alongside, directing practices, it also creates 'users' by allowing them given affordances. In Akrich's own writings she describes a portable light fixture which was distributed in sub-Saharan Africa. The length of the power

cable and orientation of the light led to its having to be used in particular ways. In another well documented example, the Kodak-Eastman camera company had to build a new set of users for their consumer (rather than specialist) camera equipment [68]. The resulting 'amateur photographer' figure can be seen as a result of the technology rather than a driver of it. In this way Oudshoorn and Pinch argue that "users and technology are seen as two sides of the same problem - as co-constructed" [67] (p. 3). As part of this co-construction, technologies frequently work to "articulate subjectivities" (ibid). In STS literature this is frequently explored through medical assistive technologies [64, 65, 69], but could be equally understood in the role GNSS-driven location-based services perform in mapping behaviour patterns, predicting where a user will be and designing and launching a program of targeted advertising. This in turn can intersect with the construction and performance of genders, sexualities and other contested social demographic constructions.

Inscription dovetails powerfully with blackboxing because the strength of inscriptions relies on the coherence and durability of their surrounding actor networks, while strong inscriptions are often submerged and invisible. Hanseth and Monteiro argue that:

> "Analytically viewed, the strength of an inscription relies on three aspects: the size and complexity of the surrounding actor-network which is linked to the inscription, the degree to which it is aligned with this surrounding actor-network and the strength of the inscription on its own." [5] (p. 22)

Through alignment with their surrounding actor-network, infrastructures lend themselves particularly well to blackboxing and strong inscriptions. For Bowker, they are "usually perceived as something "just there," ready-at-hand, completely transparent, something upon which something else "runs" or "operates" [9] (p. 99). This may happen in terms of hardware or in terms of a set of design conventions or enforced standards [8, 10]. Thus, strongly aligned with their surroundings, inscriptions exist at once as a consequence of the design process and a re-enforcement of it. As designs are iterated, successive inscriptions draw from previous blackboxing processes, thereby becoming more

transparent. Indeed, the transparency of infrastructure is frequently understood as something desirable within HCI and therefore inscribed into designed objects and services. The influential computer scientist Mark Weiser famously claimed that: "A good tool is an invisible tool. By invisible, I mean that the tool does not intrude on your consciousness; you focus on the task, not the tool" [70]. HCI researcher Sturla Bakke identifies a trend in HCI such that "the cultivation of an [information infrastructure] would benefit from hiding the infrastructural complexity beneath an easily comprehendable user-interface" both to make an interface easy to learn for new users and to offer quicker ways for experienced users to complete their tasks [71]. In keeping with this trend, Weiser argued for a type of ubiquitous computing which should recede into the background, ultimately becoming an ambient part of the environment [72]. The invisibility valorised by Weiser, however, may also emerge less from a technology's physical placement and more through the aspects of its use. HCI researchers Heer and Khooshabeh argue that invisibility in human centered design is primarily a phenomenological construct, the capacity for infrastructure to become "tacit in thought and action for human users" relies on an emergent combination of human and structural actors as well as the role played by designers through inscription. ANT-influenced approaches have also worked to critique the figure of the user as a focal point for the design process. The user may act as a prop or "narrative device" for the structuring of political and economic relations [73], while technologies may also construct types of public and citizenry [74].

In terms of GNSS, the worlds two most popular smartphone operating systems can provide a useful illustration. Developers working with Apple's iOS platform (current version at time of writing: 10.3) are able to query a device's GNSS sensor to establish the horizontal and vertical accuracy of the device's location at a given time. In these terms, the information available focuses firmly on the blue dot marking the user's position. The information which can be called must centre on the successful operation of that positional metric. The Android operating system (current version at time of writing: Nougat 7.1), on the other hand, allows the developer to call a much broader set of

information. Developers can access information about the number of satellites visible to the device's sensor, and, using a combination of the *GpsStatus* and *GpsSatellite* classes, call the unique identifying number of each satellite, their azimuth and check the presence of almanac data which allows the device to compute a location. While these affordances are not used by the vast majority of developers, their existence marks a strong difference with iOS in the understanding of where meaning lies. For iOS, location is to be understood purely in terms of user position, the only parameter of interest is the extent to which current accuracy varies from the optimal location fix. The android system, on the other hand, offers the potential to access detailed information about the infrastructural processes at work in providing that location fix.

3.4.3 What is hidden

So, through a dual and intersecting process of blackboxing and inscription, infrastructural elements which necessarily support the operation of GNSS services become obscure and invisible. At the same time, GNSS systems such as GPS become macro-actors able to shape the world around them to their own interests and requirements. Political, operational, military and technical requirements and affordances which are intimately connected to the existence and functionality of GNSS are hidden. Artist Trevor Paglan's *The Other Night Sky* project (2007-2011) and geographer Stephen Graham's work [11] have worked to visualise and map military aspects of satellite infrastructure in the sky and on the ground as political critique (although Paglan's work also draws on aesthetic renderings of hidden infrastructures). While these political implications may not directly impact individual user experiences, drawing on an ANT approach, they are vital to understanding what is happening in sociotechnical practices. Therefore, in the next section I describe ways in which these implications can be drawn out and made visible through examining their histories and effects, and observing moments of breakdown.

3.4.4 Infrastructural Inversion

Infrastructures are influential. They provide affordances for the ways in which tasks can be completed and therefore structure practices and the emergence of figures such as 'user' and 'designer'. Bowker and Star point out that infrastructures, while often thought of as hard technical systems such as an electricity grid, include ways of organising information such as forms, files and binders [8]. Architect Keller Easterling [10] builds on this idea to draw attention to the international ISO standards which exist for areas as diverse as manufacturing practices and environmental pollution. Thus, there are international standards for the size of tetrapacks holding milk and juice, just as they are international standards for accepted levels of noise pollution. These standards are also a kind of infrastructure which is influential in forming practices and objects. However, through their ubiquity, these standards tend to become invisible, it becomes unremarkable that tetrapacks in different countries conform to similar quality standards. Infrastructural inversion fights against this tendency of infrastructure to disappear, bringing it into view by leveraging points of tension within its smooth operation and by proposing counterfactual paths of development.

Despite the above examples, it is difficult to pin down what an infrastructure 'is'. The term describes diverse formations of technical and organizational objects and practices. In their influential article, Star and Ruhleder instead argue that "infrastructure appears only as a relational property, not as a thing stripped of use" [6] (p. 113). As such, we can understand infrastructure through "changes in infrastructural relations" rather than the causal agency of people or things. For Star and Ruhleder, infrastructures may vary in type and scale, but are understood through the impact they make on surrounding relations. We can read this theoretical position alongside ANT accounts which emphasise the ways in which objects emerge through their attendant relations [63, 75]. For Star and Ruhleder, infrastructures are diverse, but can be said to emerge with eight dimensions: Embeddedness; Transparency; Reach or scope; Being learned as part of membership; A link with conventions of practice; Embodiment of standards; Being built on an installed

base; and becoming visible on breakdown [6]. While all of these are significant, I intend to reflect in detail on three of these dimensions: Embeddedness; Transparency and Visibility through breakdown.

Here embeddedness is understood as being when "infrastructure is "sunk" into, inside of, other structures, social arrangements and technologies" [6] (p. 113). In the case of GNSS, we can understand the infrastructure as being embedded into a smartphone or sat-nav unit, making it difficult to comprehend as a separate technical assemblage. Transparency is when the "infrastructure is transparent to use, in the sense that it does not have to be reinvented each time or assembled for each task, but invisibly supports those tasks" [6] (p. 113). In software terms, an example of this would be the use of the last available location fix in Android and iOS operating systems. The hardware does not need to re-implement the process of establishing a fix from scratch, but can instead create a smooth and seamless user experience. Both of these properties, therefore, draw strongly from design inscriptions; the focus on the ease of a task, rather than seeing infrastructure as a tool leaves it obscured in everyday use.

In contrast, visibility on breakdown is a meta-property concerned with seams and seamlessness: "The normally invisible quality of working infrastructure becomes visible when it breaks; the server is down, the bridge washes out, there is a power blackout. Even when there are back-up mechanisms or procedures, their existence further highlights the now-visible infrastructure" [6] (p. 113). One method described in the following chapter works explicitly to leverage this infrastructural property, emphasising moments of breakdown in order to make the working infrastructure visible. This approach follows the principles of infrastructural inversion laid out by Bowker and Star [8]. There are many ways to apply infrastructural inversion, but all share a drive to recognise "the depths of interdependence of technical networks and standards, on one hand, and the real work of politics and knowledge production on the other" (p. 34). This work is often done historically, unearthing the contingent preceding and parallel infrastructural conditions through which, "the initial claim came a posteriori to be seen as reasonable"

[7] (p. 235).

Bowker and Star's work around infrastructural inversion has proved highly influential in STS circles. Here scholars have argued for deep research into the ways in which a particular paradigm emerged, allowing us to understand its contingency by "shifting the emphasis from changes in infrastructural components to changes in infrastructural relations" [9] (p. 99) (for example: [76–78]). Alongside a theoretical understanding of infrastructures as relational, we can also note their influence on the practices which they support [5]. As described above, this co-production deeply implicates active, 'doing' infrastructures in a process of ongoing inscription. By using infrastructural inversion to make these actions visible, we can produce richer and more engaged theoretical understandings of technical systems and relations which are frequently taken for granted. For Easterling this inversion can be a step to understanding the "disposition" of a technology or organisation, where disposition is "the character or propensity of an organisation [or technical infrastructure] that results from all its activity... not the pattern printed on the fabric, but the way the fabric floats... Not the object form, but the active form." [10] (p. 21).

For Bowker and Star, infrastructural inversion can engage with several methodological themes: Ubiquity; Material; Texture; The past as indeterminate and; Practical politics. Ubiquity is understood as the "layered, tangled, textured" infrastructural "ecology" which underpins how infrastructures are used [8] (p. 36). Material refers to physical standards such as plugs, batteries, paper forms and the implementation of other standards through e.g. software (39). Texture here refers to ways in which an organisation or infrastructure is understood by those who use it, in examining texture, we may pay particular attention to metaphor (p. 40). Texture is a key concept in this thesis and, I argue, can be accessed by poetic methods which incorporate a detailed and extended use of metaphor. The past as indeterminate refers to the ways in which infrastructures of knowledge can order our experience of the past, eliminating paths which were not taken and developments which were cut short (p. 41). The practical politics of an

infrastructure refers to decisions about which elements are made visible and what biases these decisions expose (p. 44). The work in this thesis touches on all these aspects, but the idea of texture is key.

Infrastructural inversion is theoretically valuable because it allows us to access perspectives which may have been closed through the naturalisation of infrastructures as a result of blackboxing, inscription or simply repeated use. It is especially powerful in combination with ANT through the way in which it allows 'submerged' infrastructural elements to be understood as active and influential actants working to form our sociotechnical practices. As such it offers a powerful explanatory tool for researchers to re-examine existing formations and propose new ones.

3.4.5 Intra-action

In this section, I would like to dive deeper into the theoretical understanding of the relationship between user and infrastructure. The interrogation of this theme guides the research questions, my grounding in locative media art and my use of design methods. In particular, I would like to critique the idea that the user and the infrastructure are distinct entities which act on one another. Bowker and Star argued that infrastructure should be known by what it does rather than what it is. Here I draw on Karen Barad's work to argue that it can only do anything through its interdependence with other human and non-human elements. This is the underlying ontological question which I would like to address through the interrogation on blackboxing and inscription. As described above, I think that, skilfully used, infrastructural inversion and speculative design allow us to ask questions around the interdependence of users and infrastructures.

The inscription and translation concepts offered by Akrich [3] and Akrich and Latour [4] leave room for both user and designer to be co-configured and, crucially, also leaves space for the designed object to become active in the way practices are produced. For this project, it provides a useful way to emphasise the agency of the infrastructure itself

in producing sociotechnical practices.

Barad [13, 14] proposes agential realism as a means of understanding the material agency of the non-human and (infra)structural. It is through agential realism that matter which is "agentive" and "not a fixed essence or property of things" becomes stable. She argues that this is not a causal process between discreet agents, but an "intra-active" process:

> "Changing patterns of difference are neither pure cause nor pure effect; indeed they are that which effects, or rather enacts, a causal structure, differentiating cause and effect" [14] (p. 137)

Matter is a congealing of agency, which takes place across intra-active processes. The dynamism of intra-activity is a key point. The constituent parts are not stable, but rather constantly being co-created. In this way, agency is not a property which a pre-existing someone or something has, but is rather an "enactment" of certain conditions:

> "Agency is "doing" or "being" in its intra-activity. It is the enactment of iterative changes to particular practices - iterative reconfigurings of topological manifolds of spacetime-matter relations - through the dynamics of intra-activity" [14] (p. 178).

So, the infrastructure, user, designer (or indeed military, satellite and software) are not pre-fixed entities which enter into causal relations with each other. Rather each of them emerges across an intra-active network defined by its relationality.

This approach offers us several things. Principally it gives us an account through which to speak about the influence and importance of non-human aspects of GNSS infrastructure and use, allowing them to exert an influence on sociotechnical practices in a richer way then as a series of causes of or effects from human action. Through this, we can craft a richer understanding of infrastructure; rather than understanding it as something hidden or concealed from users and designers, we can interrogate how those

concealments or reveals intersect with other concerns. The dynamism offered by this account also gives us the flexibility to consider the wide variety of formations and uses of GNSS. We can talk about the agency which emerges across particular combinations of satellite constellation, hardware, software, environment and intention. This emergent causality can be described as intra-action. The relevance of both this term and the complementary idea of "entanglement" has already been mentioned through Southern's analysis of Nikki Pugh's work on GNSS infrastructure [30]. Like my own project, Pugh's work, situated in an art context, uses the creation of objects and experiences to tease out these themes.

3.5 Ethnography: Analysis and Action

Ethnography has taken on a rich life within a variety of disciplines. From its emergence as a tool in remote fieldwork in anthropological contexts [79–81]. It has gone on to be highly influential in a number of disciplines including, increasingly, HCI research [82]. A broad definition of ethnography would describe a process of watching, listening, asking and recording social activity and then a process of structuring this data through categorising, iteration, theorising, and storytelling. These two processes are often far from separate. Indeed, I take a position influenced by constructivist grounded theory approaches [83–85] that the framing of a study, the data collection and then data organisation and presentation are deeply intertwined and must inform each other as the research is iterated. As sociologist Karen O'Reilly points out, the diverse uses of ethnographic techniques across disciplines and outside the academy mean that limits of what makes an ethnography are difficult to judge [86]. Alongside this divergence in applications, methodologies such as sensory ethnography [87] and multi-sited ethnography [88] complexify the ways in which data can be collected. Recent post-qualitative methodologies [89, 90] begin to extend ethnographys reach beyond the human, incorporating rich understandings of materiality that address non-human actors to understand emergent

sites and practices.

My work here is oriented alongside several of these developments. By taking a sociotechnical position that allows for the productive role of infrastructure in forming practices, I incorporate a focus on materiality to the staging, collection and analysis of my data. I also ask participants to engage in a sensory experience of site at the point of data collection. In this I was particularly influenced by walking methods. These are described in more detail in the following methodology chapter, but, in brief, point to what theorist Michael Sherringham has described as "a style of tactile apprehension and kinaesthetic appropriation" [91], where allowing the participant to walk as part of the experiment opens up potential for a richer participant experience and, thereby, richer data. Anthropologist Tim Ingold argues that "walking down a city street is an intrinsically social activity" [92] (p.43) through a person's conscious and unconscious interactions with the other people around them. In my work, I ask people to walk with a device that gives them information about the actions of GNSS infrastructure. In this way, building on Ingold's description, I leverage walking to turn it into a sociotechnical rather than social activity.

3.5.1 Ethnography and STS

As with much other theory outlined in this chapter, I draw on a tradition of ethnography as it is oriented through STS. This field is extremely broad, so it is difficult to describe discreetly what an 'STS-approach' to ethnography is, but I can make some general points and point to a few key innovations from this meeting of disciplines. In this section all scholars work within an STS context unless otherwise noted.

In contrast to much early anthropology work, the field site in STS is typically not remote. It often takes place within the author's own society. The first generation of scholars in the 1970s and 80s used ethnographic techniques to study scientists and the production of scientific knowledge. They used ethnography to break away from the posi-

tivist idea of science as purely rational, arguing instead that scientific knowledge emerges from the meeting of social and disciplinary conventions and the technical parameters of the laboratory. For Latour and Woolgar, study of laboratory conditions and the writing up of findings shed light on how observations in the lab came to be understood as widely accepted facts [93]. Throughout the 80s, STS took what Woolgar has called a 'turn to technology' [94] and began to develop wider theoretical work about how technology and society shaped each other. As analysis stretched beyond the original site of data collection, Hess argues that such work became multi-sited [95], interested in exploring how technology and knowledge emerge at a society-wide level across multiple sites and practices, rather than in a discreet laboratory or profession.

It bears remembering that STS, and the tools emerging from an STS tradition are cross-disciplinary and operate differently in different contexts and with different objects of study. A sociomaterial turn within organisational and management studies has embraced the stress STS puts on the formative power of technical systems to study conditions in specific workplaces [96, 97]. Sites of interest have included hospitals [5] and airlines [98]. This is to emphasise that, despite its theoretical abstractions, much STS work continues to base itself in detailed ethnographic fieldwork. Even work as grand in scale as Paul Edwards' study of the emergence of climate modelling, is based in multi-sited ethnographic study of the practices of climate researchers [99].

While early STS scholars emphasised 'impartiality' as an important principle in their work [100], a more recent wave of work has argued such work is necessarily 'partial'. Marilyn Strathern understands partiality in two ways; firstly that there is no totality, each part also defines a partisan position and secondly that "ethnographic truths are partial in being incomplete and committed" [101] (p.39). In this commitment ethnographies also act, necessarily taking up a political position, although what that position is frequently remains undetermined. Winthereik and Verran draw on Strathern's dual notion of partiality and what Haraway has called "double vision" [24] to present both "lived social and bodily realities" and theoretical abstractions that seek to intervene pos-

itively in their fields of inquiry. Such commitment has lead STS scholars to take positions that aim to critique and influence (amongst many other topics) healthcare [102, 103], education [104] and climate science [99, 105].

Another major shift in STS-influenced ethnographic work is an attention to materiality as it pertains to non-human actors. The importance of technology in forming social (or rather sociotechnical) relations has been an ongoing theme in this work, but more recent work also seeks to engage with other beings. Kirksey and Helmrich argue that engagement with other beings should be understood specifically in ethnographic terms. Their proposal for 'multi-species ethnography' brings animals, plants, microbes and fungi to the foreground of scholarly attention through the ways the lives and deaths of these organisms are "linked to human social worlds" [106]. Elsewhere, Lien and Law [107] use material semiotics from actor-network theory to describe the emergence of new kinds of salmon through an examination of intensive salmon farming practices in Norway. The argue that the action of farming practices creates new types of fish, both through the emergence of farmed salmon and through the creation of its opposite 'villaks' (wild salmon), a term that arose alongside the rise in salmon farming since the 1970s. The ethnography here addresses the salmon within a larger apparatus of attendant actants and processes, it provides an ethnography of salmon not by looking at it in isolation, but through its emergence across a breadth of actions and practices. These "distributed forms of agency" [107] (p. 79) can provide a powerful way of re-imagining how we approach ethnography, using tools that seek to understand the assemblage or apparatus at large and asking questions of the apparatus that need not focus on human subjects or practices. In short, this attention to materiality points to the way practices and bodies are constantly being remade through a series of interactions between subject, site, practice, infrastructure and other species. By arguing that these aspects are, themselves contingent and emergent, their boundaries also begin to fade. Such a shift towards sociomateriality allows 'technical' elements to have a greater role in how we theorise the emergence of practices. As I argue below, such an overlap must be considered at all

stages of the ethnographic work; staging, collection, theorisation and iteration.

A different approach to the ethnography of non-humans is Chang et al's work around the scooter in Taipei [108]. They collected extensive mobility data on a number of scooters, developed characters based on that and employed actors to give voice to each scooter, using the results of the interviews as ethnographic data. While this work may seem strange, arguably the process of writing a character and having it performed by an actor is just as much of an abstraction as using a sorting algorithm to process quantitative data. The work demonstrates the radical shift in positioning and expectations required to address non-human actors. Such an approach echoes the space Haraway allows for metaphor to enter theory. Arguing for a recognition of the dual literary and literal nature of Biology, she writes: "I want to call attention to the simultaneity of fact and fiction, materiality and semioticity, object and trope" [109]. Allowing space for literary, or poetic qualities of the non-human allows us another way of describing and exploring how they act. Such an approach is consistent with the idea of poetics I advance in this thesis. In another point of synchronicity with Haraway's work, following Bowker and Star [8], I argue for a leveraging of metaphor (through speculation, metaphor and art practice) as a way of enriching our understanding of the action and agency of the material.

3.5.2 My practice and ethnography

Despite the fact I draw on examples that reach beyond traditional ways of doing ethnography, I hold on the term to describe my work because of the importance I place on empirical work with participants. I work with designers, engineers and users to probe how GNSS infrastructures form our sociotechnical practices. Understanding my work as ethnography allows me to use empirical research as a starting point to make wider theoretical claims about the way infrastructures form practices. Working with participants using staging and the eliciting of reflection to get a deeper, diagnostic sense of these interactions thereby allows me to draw on more than my own isolated theorisations. Participation has long been part of my art practice and, although it has taken

many different forms, I have always strived to have the audience contribute to the final work. In this thesis, following Haraway, [24], I seek to use an empirical ethnographic foundation to create a "double vision", exploring both how GNSS infrastructures create our practices in a diagnostic sense and how we might speculate about shifting ontologies and alternative configurations and theorisations.

The work I describe in this thesis pays special attention to the "texture" [8] of GNSS infrastructures. These textures, in keeping with the sense of transparency which comes with infrastructures [6], are not immediately apparent, especially to participants. In order to make these textures less transparent, I use poetic techniques to foreground them. This provides a break with the majority of ethnographic techniques in which a researcher goes into a situation or organisation, observes, listens and conducts interviews. Even more staged interviews like the 'walking and talking' methods described above [91, 110, 111] stick relatively closely to this model. The majority of work that engages with infrastructural inversion as a key concept works historically, exploring the development of a now transparent infrastructure and asking what could have been different [7, 112]. Other scholars interrogate infrastructure using ethnographic methods, but frame the work in philosophical traditions that do not give equivalence to the agency of the infrastructure (e.g. Henfridsson and Bygstad's use of critical realism [98]).

By engineering an infrastructural inversion and using it as the starting point of the study, my work brings the staging of the research into the foreground. In this way, it stretches the boundaries of what has been traditionally understood as ethnography in the interview or observational sense. However, I feel that, in my case, research techniques must seek to produce infrastructural inversion as a starting point, rather than deploying it as an explanatory historical or theoretical tool after the fact. I choose to draw these techniques from art practice because of their effectiveness in creating moments of defamiliarisation and revelation. In this context, these moments are not sought for their own sake, but rather to catalyse participant awareness and reflection in relation to GNSS infrastructure. This attention to poetic staging provides an innovation on existing

work through an attempt to enact the theoretical concept of infrastructural inversion. It also offers a route to pedagogically engage with participants around issues of material agency. A similar critical pedagogic drive can be seen in design approaches described later in the literature review such as Critical Making [21]. This drive is, however, rare in the ethnographic literature.

3.5.3 Ethnography and Data Analysis

When using theory to interrogate ethnographic data collected from interviews and participant observation, there is a danger of assuming that theoretical readings sit apart from the data. Following Latour [75], Law [113], Mol [63] and Barad [13, 14], I argue that research is not separate from the data it collects, but rather emerges across a broader apparatus. In this work therefore, I choose to follow ethnographic approaches which draw on with a more fluid view of how theory, data and data-collection work together.

A highly influential approach for the collection, iteration and development of knowledge in social research is Grounded Theory. The emergence of the approach through the writings of sociologists Anslem Strauss and Barney Glaser [114] is well documented [85, 115, 116] and involves the collection of data and the development of theory which is then re-iterated through the collection of further data and thematic analysis. There has been some debate through the years over how much influence theoretical concepts should be allowed to exert on analysis [83, 117]. Since the 1990s a somewhat constructivist consensus has emerged around a group of practitioners including Adele Clarke, Antony Bryant and Kathy Charmaz [84, 118–120](and see [85] for a detailed account). This approach retains the importance of the emergence of theory within the research situation, but acknowledges that, whether we like it or not (or are conscious of it or not), the theoretical predilections we bring to our work exist and are influential. This makes it extremely difficult to start from a blank slate, see the researcher as independent of their training, and all theory as emergent from empirical work in the way proposed by Glaser [117].

The forms of knowledge which are produced by research can also be seen as infrastructures in the sense of being what Adele Clarke and Susan Leigh Star call "frozen discourses that form avenues between social worlds and into arenas and larger structures" [121] (p. 115). We can incorporate these concepts into our findings through what Clarke calls a "Situational Analysis" [84, 118] which takes into account how the research is staged. Through producing a series of iterative charts, situational analysis aims to incorporate researchers' questions, existing conceptual approaches and the staging of the study alongside other epistemologically important elements such as relevant media narratives and non-human elements (e.g. technologies of work, organisational structures). In this way, Clarke acknowledges, situational analysis shares some features with the infrastructural inversion proposed by Bowker and Star [84], but the infrastructure being inverted here is the research process itself. By drawing attention to the interactions around research staging and the influence of research discourses and tools, situational analysis also leaves room for the material agency described by Barad, allowing the role of non-human elements to be acknowledged the emergence of theory.

Again, here it is worth noting the importance placed on a researcher's engagement. Material agency and intra-action are not passive theories, by this I mean they do not merely describe a situation, but can and should also intervene. Barad argues that:

> "Agency is about the possibilities and accountability entailed in reconfiguring material-discursive apparatuses of bodily production, including the boundary articulations and exclusions that are marked by those practices in the enactment of a causal structure." [13] (p. 827)

In other words, the way agency operates matters through the types of bodies and objects which are performed and produced by material-discursive apparatuses. Barad, along with Haraway [15, 24] and Clarke [17] propose a feminist understanding of technoscience which is critical of the ways in which dominant discourses have been produced. The work of research is, in part, to take action and intervene in the processes at work. Clarke proposed that situational analysis can:

> "Turn up the volume on lesser but still present discourses, lesser but still present participants, the quiet, the silent, and the silenced... They often tend to be female or otherwise "othered," possibly including the nonhuman. Situational analysis focuses on making the less powerful, silent, and silenced more visible and more analytically central." [17]

In my own work I argue for a similar engagement through building a greater focus on the non-human through attention to the infrastructural processes which influence our practices. By making them visible and giving prompts for alternatives, I intend to leverage poetics to offer alternative ontologies and, thereby, alternative power structures. While these may not be realised in full in this project, the act of thinking about alternative ontological approaches to the way we use GNSS creates space for dramatic re-imaginings and generative potential. In this way, the work opens space to reach beyond the present state of things and offer shifting and alternative conceptual and ontological understandings.

3.6 Alienate, Critique, Re-imagine

In the remaining sections of this chapter I review some further approaches which can be said to engage with design inscriptions, working to invert or alienate them. Inscription operates hand in hand with infrastructural blackboxing to create fixed formations of user, tool and practice. By challenging the accepted sociotechnical practices of users and roles of designed objects, we can begin to offer critique of and alternatives to these practices, making inscription visible and destabilising blackboxed objects. This process can provide shifts in the ontological and conceptual landscape through which we understand 'user' and 'infrastructure' as distinct entities. Many of the approaches outlined below emerge from the amorphous and varied field of 'critical design' (though it should be noted that the boundaries and unity of this term are highly contested). In particular, I concentrate on speculative design which often uses fictional scenarios to reframe

a problem or challenge an existing situation. Used in this way, speculative design can deploy poetic approaches to provoke radical shifts in established practices and ontologies through the suggestion of new and alternative worlds.

3.6.1 Breaking Design Inscriptions

The process by which we can invert GNSS infrastructure has potential applications for both theoretical understanding and generative design. In this section I describe the reasons why it is desirable to challenge the embeddedness and transparency which are common features of infrastructural relations. This literature looks primarily at HCI and design literature as opposed to theoretical work and concentrates on ways in which dominant patterns of use are challenged and broken. While this does not directly link to the subject of GNSS, it offers ways to re-orient our socio-technical practices, making visible the infrastructural bases that underlie our use of technologies. Such work is relevant to the methods I develop to critique GNSS.

HCI researchers Matthew Chalmers and Areti Galani [122] propose "seamful design" as a way of critiquing the "disappearance" of computing valorised by Weiser. They point to interdependence between different types of media and the moments of breakdown between them as sites which designers can leverage to produce new experiences. For example, the "breakdown" where a cellphone loses signal and the focus of the user shifts from the task (as understood as taking place "through" the tool) and back to the tool itself. At this point we may become aware of a "rich, but complex process of interweaving, accommodation and appropriation" (ibid) from other media and symbolic inputs. This process has great potential for designers to change the nature of the experiences being offered and for users to incorporate these breakdowns into their practice to create new modes and tactics of use. Indeed, in a study based on interviews and diaries, interaction design researchers, Louise Barkhuus and Valerie Polichar argue that Chalmers and Galani's idea of seamfulness is already a reality for many smartphone users who leverage a device's limitations for a greater sense of empowerment in using

the technology [123]. In this way they can be understood as breaking through design inscriptions [3] to open up sites of translation [4].

Breaking through design inscriptions to create more empowered users also offers promise for participatory design approaches. Within this field, Christiano Storni offers seams as a means of producing "empowerment-in-use". He argues that "When things can be seen (when they are made public and accessible), they can then be accounted for, debated, discussed, and acted upon."[124] (p. 168). The resulting awareness on the part of users can help designers, particularly those using participatory techniques, to achieve deeper levels of critical engagement from participants.

If attention to seams can prove useful for users, it can also offer a similar deepening of critical engagement to designers. HCI researchers Genevieve Bell, Mark Blythe and Pheobe Sengers argue for "defamiliarisation" as a reflective design tool [125]. With particular attention to domestic technologies, they argue that "making domestic life and technologies strange provides designers with the opportunity to actively reflect on, rather than passively propagate, the existing politics and culture of home life and to develop new alternatives for design." (p. 150). In this desire, they draw from Senger's other work in which she proposes reflective design as a critical paradigm [126]. The defamiliarisation proposed by Bell et al draws explicitly on a literary technique which "compels the reader to examine their automated perceptions of that which is so familiar that it seems natural and so unquestionable" [125] (p. 151). We might also consider the relationship to situationist art practices. Through derives (directionless walks through the city), situationists such as Guy Debord and Asger Jorn [58] worked to make the familiar unfamiliar and thereby allow new ways of interacting with the city. As Tuters and Varnelis argue, these techniques proved to be highly influential on the first wave of locative media art projects [37].

While defamiliarisation should not be seen as interchangeable with seamful design, both share a desire to uncover the invisible assumptions which support sociotechnical practices. In its bare form, a seam may be understood as communication between two

software protocols, made visible by a moment of breakdown. However, in richer terms, we may consider such an interaction as being supported by a series of social and technical standards and infrastructures, underlying common sense assumptions and passively propagated design inscriptions. In this sense both defamiliarisation and attention to seams act as infrastructural inversions. They seek to turn existing systems on their heads, ask how they came to be and how they could be different. As Bell, Blythe and Sengers argue, this process can have value for both users and designers, acting as "a lens to see our own design [and use] practices in a new light" [125] (p. 154).

3.6.2 Design Approaches

The practices described so far in this chapter focus on deepening engagement with existing practices, but creating awareness of infrastructure also has the potential to generate new, critically informed designs. In this section I will describe critical and speculative design; approaches which aim to produce concepts which question existing relationships with technology. Many of these approaches also interrogate design's obsession with usability and, by extension, the figure of the user. They may both critique specific design inscriptions, and, go further to question the terms on which those inscriptions take place. Pointing to this broader aim, I argue that speculative design offers a way of creating alternative worlds. These alternative realities subvert the power of both blackboxing and design inscriptions to act as macro-actors and shape the world around them. Through their ability to achieve infrastructural inversion and shift understandings of use they provide a useful set of techniques for researchers both in and outside the fields of design and HCI.

It is worth noting that I do not concentrate primarily on participatory approaches. I should also disambiguate from the use of the term "infrastructuring" in participatory design. Designers have borrowed from Star, Bowker and Ruhleder's work [6, 8] to suggest "infrastructuring" as a way of uncovering future issues, critiquing power relations and initiating or shaping publics [127–129]. While such work brings a fascinating application

of Bowker and Star's work, it applies less to my project. Because I do not focus on a given community, issue or context, I would struggle to situate this thesis in a participatory design context. Rather, the design techniques described revolve around projects which inspire critique using particular participant groups, but in a broader context.

3.6.2.1 Critical Design

In this section I describe several different critical design approaches, giving a brief overview of their development, discussing the ways in which they have been incorporated into HCI approaches and thinking about what they offer as tools to critique established sociotechnical practices.

Critical design is a slippery term and has been contested over the years. For the sake of brevity and because of its relevance to my own approach, I will start the discussion with Anthony Dunne's book *Hertzian Tales*, first published in 1998. Here, Dunne argues the need to stretch design thinking beyond a mimetic approach based on familiar representations of electronic objects. Under this rubric, "[d]esigners using existing codes and conventions to make new products more familiar often unconsciously reproduce aspects of the ideology encoded in their borrowed motifs" [19] (p. 30). Rather, Dunne proposes a more poetic use of design objects to "provide conditions where users can be provoked to reflect on their everyday experience of electronic objects [and] to encourage skeptical sensitivity to the values and ideas this environment embodies" (p. 42). He argues that such an approach can be brought about by suggesting alternative functionalities, providing a form of functional-estrangement. While the term was coined by Dunne and Raby and initially referred to work conducted by those working in their immediate circles, Dunne and Raby acknowledge that now:

> "There are many people doing this who have never heard of the term critical design and who have their own way of describing what they do It's more about values and an attitude, a way of looking at design and imagining

> its possibilities beyond the narrow definitions of what is presented through media and in the shops." [130]

At this point it is useful to give an example to illustrate the technique. In their book Design Noir [131], Dunne and Fiona Raby describe a project called *GPS Table*. The table, equipped with a GNSS sensor, is placed in a family home. If it achieves a location fix then it displays a green light, otherwise it displays a red light and the message "I'm lost". The table's owner is therefore encouraged to take the table outside where it is more likely to get a location fix. The designers hope that the owners feel bad about always keeping it inside, thereby giving the table "a sense of being alive". It should be noted that this project was developed in the early 2000s before GNSS became a widely adopted technology. This unfamiliarity contributes to 'functional-estrangement' from how a table typically acts. The book contains an interview with the table's owners who report that it became a presence in the house. They would check before going to bed if the table was 'lost' and feel a duty of care if it was. As such, the table becomes separated from its familiar uses, taking on a new, more poetic role in the home.

A more recent project with a similar theme, *Satellite Lamps* (2014) by Einar Sneve Martinussen, Jorn Knutsen and Timo Arnall, proposes a series of lamps which become brighter as satellites pass overhead. The designers offer the project as a means to "explore, find and generate awareness, sensibility, and new understandings of both GPS's technical and cultural invisibility" [132]. Their approach invokes Sengers's reflexive design [126] when they state:

> "we aim to explain and remind rather than to emphasize the critique. To be able to articulate how GPS takes place in the city, we also need to deeply examine and understand GPS as designers."

Here the critique is understood as process and carried out as much by the designer as the audience, leading the authors to characterise their approach as "discursive design" [132, 133].

The creation of such objects continues to provide a rich vein for critical, reflexive, discursive and other self-characterising designers. Besides Dunne and Fiona Raby's own students at the Royal College of Art, we can find notable examples in the Sentient City collection curated by Mark Shepard [134], or the work of artist Natalie Jeremijenko [135]. While these designers or artists would not necessarily describe what they do as critical design, Dunne and Raby's definition leaves room to understand artists as working in a similar way. Indeed, in discussing complementary practices, they specifically mention Jeremijenko along with artists Krzysztof Wodiczko, Jurgen Bey and Marti Guix [130].

While acknowledging the allied status of other artists and designers, Dunne and Raby impose certain conditions on their own 'critical design' work, particularly through a tension in how these objects are staged for viewers. Drawing on his background in industrial design, Dunne argues against understanding critical design objects as art and, if they are shown in a gallery, prefers to think of the gallery space as a "showroom" [19] (p. 100). Projects may also take place in site-specific contexts and as interventions in public space.

The influence of critical design has historically entered into HCI discourses indirectly through the above divergent techniques, but a recent debate has tried to engage with critical design in HCI as a unified concept. Jeffrey Bardzell and Shaowen Bardzell have queried the criticality of critical design. Attempting to incorporate it into a Frankfurt school tradition of critical theory, they argue that critical design "holds the design profession to account for its complicity with capitalist ideology and alienation"[136] (p. 3298). In their implementation, "provocativeness" becomes a major design concern, and one by which to measure the success of the design. Indeed, it could be argued that provocativeness is similar to more traditional HCI measures around 'engagement'. They ground this claim in Dunne's *Hertzian Tales*, focussing on his argument that critical design can work to challenge dominant ideologies.

In response, James Pierce et al [18] argue that, rather than take critical design as a fixed approach with a set of evaluable criteria, it should be understood as contemporane-

ous both with other design approaches and avant garde artistic approaches. In this way, "there is a 'critical' tradition in design and the arts that is largely independent of critical theory and metacriticism" (p. 2086). Viewed this way, critical design is concerned with tactical approaches rather than ontological categories; so, when Dunne and Raby argue that their work should not be understood as art, we should see the tactical benefits offered by positioning it as design. Design objects are more likely to be understood as functioning products rather than abstract concepts and, as a result, more effectively provoke thought. Pierce et al also note that, through an attention on authorship, critical design moves away from the audience-centered metrics proposed by Bardzell and Bardzell [18] (p. 2089). In order to allow contemporaneous design approaches room to breathe, Pierce suggests retiring or curtailing the use of the term critical design, which has been increasingly used as a catchall for "the broad range of design practices that convey an authorial voice with critical dimensions as an alternative to (but not a replacement of) user-centered design" [18] (p. 2091).

For my own part, I draw on critical design because of its ability to re-frame familiar objects into new situations and, thereby, create experiences that challenge existing or accepted patterns of use. However, I emphasise a position that is more open-ended than the vision offered by Bardzell and Bardzell. I am not so much interested in critical design's ability to hold specific economic and political assymetries to task. Rather, in a way emergent from my art practice, I work to re-frame existing sociotechnical relations in a context of fiction, metaphor and alternative perspective. The key aspect I carry from critical design is tactical; the effectiveness of such re-framings for creating revelatory experiences. These experiences need not centre on rigorous (or un-rigorous) critical thought, but can rather leverage the affective power of re-contextualising technical objects. In this, I do not seek to work towards a set of universal criteria to evaluate the success of a critical design project, but rather understand success as the ability to engage with my own research area or, in STS researchers Cecilia Lury and Nina Wakeford's words, introduce "answerability" to my methods in relation to the research questions

[137] (a more detailed discussion of answerability follows in the methods chapter).

3.6.2.2 Speculative Design

As Pierce at al [18] note, there are a variety of emerging design processes in the 'critical design' space attempting to move from user-centeredness to critique. In this section, I describe one in detail; speculative design. This approach allows us to leverage broad critiques that, rather than talking about particular objects, concentrate on the types of world that they create. Speculative design works to build new worlds and realities, allowing a more radical acknowledgement and interrogation of the influence of inscription and blackboxing. Here I give an account of the development of speculative design, some criticisms levelled against it and a justification of its usefulness to this project.

To situate the discussion of speculative design, it is useful to begin with a definition of design fiction, an overlapping approach. For science fiction writer Bruce Sterling, design fiction is a technique which involves "thinking very seriously about potential objects and services and trying to get people to concentrate on those rather than entire worlds or political trends or geopolitical strategies" [138]. In Sterling's practice, such work is often done within fiction writing. As an emerging methodological tool, this understanding of design fiction is seeing application within HCI research [139–141]. Dunne and Raby propose speculative design as an alternative to design fiction, suggesting that design fiction emerged from the technology industry and frequently focusses on technological futures. They propose a broader approach, following writer Margaret Atwood who prefers the term 'speculative literature' to 'science fiction', they posit 'speculative design' over 'design fiction' [20] (p. 100).

Speculative design often finds its outputs in objects, services or interactions which play with the proposed world at large. This reflects a shift in design positioning, away from the idea that the design object solves an existing problem, acknowledging "that many of the challenges we face today are unfixable and that the only way to overcome

them is by changing our values, beliefs, attitudes, and behaviour" (p. 2). The space which is opened allows "discussion and debate about alternative ways of being" (ibid). This shift plays a dual role in offering futures, but also reflects back on the present to inspire "reflection, critique, provocation and inspiration" (p. 70) around existing practices. It also works to address 'wicked problems' which are based in shifting and unstable, rather than discreet, requirements [22, 23]. In this work I take 'wicked' to mean problems which are embroiled in ontological concerns around the nature of the user, the infrastructure and the worlds they operate in and produce.

Speculative design is a broad and dynamic approach and, as such, may be applied in diverse contexts. Dunne and Raby propose a number of application contexts for speculative design: Thought Experiments, Reductio Ad Absurdum, Counterfactuals, and What-Ifs [20]. The design objects which are built for these scenarios act as props to "facilitate imagining" (p. 92), but, in keeping with its focus on "alternative ways of being", the speculative approach need not be constrained to objects, it can also include the building of an alternative world at large:

"Speculative design contributes to the reimagining not only of reality itself, but also our relationship to reality. But for this to happen, we need a move beyond speculative design to speculative everything - generating a multitude of worldviews, ideologies, and possibilities." (p. 161).

It should however be noted that, for Dunne and Raby, the emergent multiplicity of worldviews and ideologies is authored by the designer. They write: "The most interesting voice, or perspective to design from, for us, and probably the most neglected, is the designer's own language." (p. 96). In this way, the power of the speculation is firmly sited in the finished design object, involving meticulous care around how it is presented, exhibited and engaged with. In his review of their work, designer Cameron Tonkinwise understands this as a noticeable break from Dunne and Raby's contemporary, William Gaver who focuses more on design process and its connection to ongoing research rather than a developmentally sealed outcome [142].

For my own part, I draw on the act of world building at the heart of speculation. By fundamentally questioning the relations on which sociotechnical practices are carried, we gain the potential to radically question the primacy of the user and the understandings created by infrastructural blackboxing. Speculative design allows us to propose scenarios where a change in some aspect of the infrastructure takes on a huge significance for our familiar practices. It provides the ability to think through design scenarios where the user is not the key focus. For me, this is part of an ongoing research process rather than the design and creation of an object. In my work, speculation is used as a poetic prompt to illicit richer responses from participants and as a strategy to re-frame technical objects which are subject to powerful blackboxing and design inscriptions. The authorship for such work does not rest solely with myself as the artist or designer. Rather I see my role as a facilitator or arranger of prompts and experiences that can feed an ongoing process of re-framing, reflection and research. The specific applications of this positioning will be considered in detail in the following (methods) chapter.

3.6.2.3 Critiques of Speculative Design

Speculative design in the form proposed by Dunne and Raby is not without its critics. Design researchers Luiza Prado and Pedro Oliveira [143] argue that, through a focus on a particular profile of designer and audience (white, straight, male), it fails to provide a space for marginalised voices from black and ethnic minority communities in the west or from the global south in general. Tonkinwise likewise criticises *Speculative Everything* for addressing global problems from a culturally homogenous position at the same time as it claims to challenge the homogenizing force of global capital. He views the frequent citing of the speculative work in technoscientific futures as indicative of this problem:

"Putting the focus on problems that we all will apparently face is a good way of excusing the need to deal with, if not concealing altogether, that there are problems today that not all of 'Us' face."[142].

Indeed, with an increased focus on authorship comes an increased focus on author positioning. This extends to modes of distribution as well as authorship. Bardzell has criticised projects which work towards the gallery or exhibition as an end point as being "elitist" [144] (p. 290).

Laura Forlano and Anijo Mathew share this critique and respond by offering a participatory, workshop-driven approach that "[took] these design practices out of the context of art and museums and mobilized them as a generative practice for our participants" [145] (p. 11). They conducted a series of co-design workshops in Chicago, New York and Boston to explore speculative urban technologies in the areas of public screens, internet of things and technologies of the body. The emerging areas of concern are described as "design frictions" highlighting a number of tensions in embedded values and the roles of participants and designer. In the description given in the paper, the future scenarios and generated designs take a backseat to a description of emergent politics of the workshop and speculation becomes a tool to enable co-design. This example illustrates an interesting tension between speculative and participatory design. While participatory design focuses on identifying existing areas of concern and acting on them, the unique value of speculative design is to re-orient those relationships. While the two need not be mutually exclusive, there is a pay-off that has to be considered. By taking speculative design out of "art and museums" it can be more grounded in everyday concerns (Forlano and Mathew's workshop requires participants to situate their design within a specific neighbourhood for example), but as a result some of the radical generative power of the technique may be lost.

In a more authorly mode, Carl Di Salvo, Tom Jenkins and Thomas Lodato offer "Speculative Civics" as a way of designing for "the modes through which individuals take on the role of citizen, involving processes of governance and politics" [146] (p. 4979). They draw on extensive research of civic issues, but the prototypes offered in the paper are not the result of a participatory or co-design process. As in the Dunne and Raby formulation of speculative design, the prototypes (division of domestic data in

divorce, governance based on aggregated sentiment data, a foraging drone) are offered as provocations, but are grounded in existing technologies "pushed to extremes" (p. 4983). As a result, the worlds offered by "speculative civics" are similar to our own. One could argue they offer critique by accelerating existing technologies, but fall short of the "reimagining" of both reality and our relationship to reality [20] (p. 161).

In both these examples a tension emerges between speculative design in a more abstract, avant-garde formation and in a form which is more applicable to existing matters of concern, particularly in given social and civic contexts. Speculative aspects can exist in many ways in the design process and the choice over where and how to apply the techniques is always tactical; a pay-off for the designer or researcher depending on the focus of the project.

My own uses of speculative design aims to walk the line between these two poles. I place the emphasis on a more far-reaching, avant-gardist approach to allow the ontological interrogation of 'user' and 'infrastructure', but I do this through inclusive design workshops. I follow designer and researcher Matt Ratto [21] to argue that the critical work in the design process frequently takes place in the making process rather than the finished object. In this way, the *process* of speculation is the element of speculative design which I embrace most strongly. By asking participants to think about fictional future scenarios, I encourage them to step outside their typical practices of use and use fiction and metaphor as a way of advancing self-reflection. In this way, I aim to find a way to bring the more abstract, conceptual and ontological questions that are such a strength of speculative design into a more engaged, participant-facing form, whilst maintaining the ability to radically re-think the problem space.

3.7 Conclusion

In this chapter I conducted an extensive literature review of work in locative media art, STS, HCI and design. Locative media art is understood as a field which has hosted and

contributed to the theory around these topics, particularly through an understanding of the performativity of location [28, 37]. In the survey of this work I concentrate on work which identifies an active role for GNSS infrastructure. GNSS infrastructure is understood as being concealed from the majority of sociotechnical practices around location by a combination of blackboxing [1] and design inscriptions [3, 5]. This is understood against a wider ontological backdrop of actor-network theory [2, 63, 113] and Baradian intra-action [13, 14]. This ontology emphasises the material agency of infrastructure, the build environment, GNSS sensors and other actions beyond the user. In order to interrogate the established positions and practices of actors implicated in these intra-actions, I suggest a series of approaches aimed at critique and defamiliarisation. After a review of the field, I suggest infrastructural inversion [8, 9] and speculative design [20] as two useful tools which intersect with my idea of poetics to defamiliarise hidden or tacit actions of infrastructure.

In the next chapter, I argue that poetic techniques can innovate on the literature described here by catalysing participant reflection on sociotechnical practices and using metaphor as a lever to elicit and understand how the textures of these infrastructures are felt to act. This combination, in addition to drawing on art practice, can address infrastructural texture in more detail than can any of its constituent parts. Poetic staging, fiction and metaphor are also offered as approaches to defamiliarise ontological understandings around the centrality of the user. In this way, poetic methods can suggest an ontological shift towards the idea of more-than-human networks in the understanding of how user and infrastructure interact.

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Chapter 4

Methods

In this chapter I will describe my methods. These poetic methods use staging influenced by art practice to destabilise blackboxing and inscription, processes which push GNSS infrastructure into the background. The methods also seek to destabilise the process whereby, as the infrastructure is pushed into the background, the user is placed at the centre of both software design and sociotechnical practices. My research questions centre around the effectivity of these techniques in accessing the 'texture' of blackboxed infrastructures and their ability to shift understandings around the centrality of the user and their place within more-than-human networks.

These poetic techniques emerge from the theoretical concerns and design strategies described in the previous chapter. The first of these is a series of 'walking' studies in which participants are made aware of the presence of GNSS infrastructure. This is done by calling attention to its breakdowns in relation to a given architectural site. The second is a set of design workshops which draw heavily on speculative approaches to propose future scenarios in which the nature of GNSS infrastructures has shifted. While both these approaches can be understood as poetic techniques, they are designed to address different research questions. The first method deals with attempts to access the texture of blackboxed infrastructures. The second method takes the inquiry deeper into

ontological territory, attempting to shift understandings around the user in relation to more-than-human networks.

Both approaches are understood as 'staged' to the extent that they create a research situation to probe a given area of concern. They do not take the site of research for granted and these are not studies that seek to go into an existing organisation or situation and document it. Rather they explore what underlying assumptions and exist and what alternative practices can be offered. For clarity I include table 7-A which offers some major points of comparison in the focus of the two methods.

Walking Method	Design Method
primarily challenges blackboxing	primarily challenges the centrality of the user
privileges spatial experimentation	privileges conceptual experimentation
reflective: discursive through observation	creative: discursive through generation
participants are users	participants are professionals (engineers and designers)
data collected through writing, drawing and discussion	data collected through conceptual prototyping and discussion
individual work and group discussion	group work and group discussion

Table 4-A: Comparison between poetic research methods.

It is important to acknowledge the positioning of the work within a lineage of locative media art. As discussed below, both methods draw on art and design techniques to create experiences designed to take participants outside their usual experiences and get them thinking in new ways. The workshop design was iterative, repeated and tweaked until the point I felt it was achieving this structural prerequisite. As such, the research experiment can be understood as a designed experience in itself. I have also used the experiments as stand-alone artistic projects or as part of broader artistic work. In all these contexts, it was intended that participants should find the experiment fun, engaging or interesting. In short, they, as well as I, should get something from their participation.

4.1 Walking Method

This method was undertaken as a way of poetically staging Bowker and Star's infrastructural inversion [1] through emphasising moments of breakdown in the smooth functioning of GNSS. The method aimed to provoke criticality around sociotechnical practices concerning GNSS and to draw attention to the presence and influence of material forms of agency in creating those practices. The technique was ethnographic in part, but deviates from traditional understandings of this term by, rather than being observational, using affective techniques influenced by art practice to stage a research situation in which existing practices are destabilised.

4.1.1 Epistemology

The act of consciously staging a study in this way requires me to take a position regarding the relationship of the researcher to the staging of the experiment and the production of research data. As I argued in the previous chapter, I hold that the researcher is profoundly implicated in the outcomes of a given study through the structures of knowledge production that support their work and the framing they put on the research experiment. To conceptualise this process, I would follow those working in STS-influenced fields; Lury and Wakeford [2] and Law [3] in emphasising the specificity of research methods. For Lury and Wakeford;

> "It is not possible to apply a method as if it were indifferent or external to the problem it seeks to address, but that method must rather be made specific and relevant to the problem. In short, inventive methods are ways to introduce answerability into the problem" (p. 2 – 3)

Lury and Wakeford's understanding of answerability is twofold, through: "the addressing of a method - an anecdote, a probe, a category - to a specific problem, and the capacity of what emerged in the use of that method to change the problem" [2] (p. 7).

Answerability requires the method to successfully *address* the research question and then participate or *engage* with it. Answerability should not, therefore be understood as the ability to provide a falsifiable answer. Specificity of method is required to ground a method in the research question, but space is required to allow it to engage with evolving and emergent concerns. In order to make the method meaningful, grounding the inquiry "somewhere and sometime"[2] (p. 7) is of prime importance. Iteration can be a means to ground the method in the specific needs of the question, thereby ensuring addressability. The need for specificity and iteration around method is also argued for by John Law. For Law, the idea of method as "a set of short circuits that link us in the best possible way with reality" must be unlearned. Instead, he proposes methods that; "will often be slow and uncertain. A risky and troubling process, it will take time and effort to make realities and hold them steady for a moment against a background of flux and indeterminacy"[3] (p. 10).

In this way, research and method are themselves assemblages which contain participant, site, participant experience and research question. In understanding how these assemblages 'act', Dilley draws particular attention to the influence of the research questions at stake, arguing: "contexts are sets of connections constructed as relevant to someone, to something or to a particular problem, and this process yields an explanation, a sense, an interpretation for the object so connected." [4] (p. 2). Law and Urry make a stronger claim that methods "can help to bring into being what they also discover"[5] (p. 395). This generative aspect of method can be understood in terms of Lury and Wakeford's second point, to ensure that methods also act to "change the problem" [2] (p. 7), a drive also present in Strathern's "partiality" [6] and Haraway's "double vision" [7]. On a similar note, Asdal and Moser suggest that methods should act in a way that can "enrich and not only reduce"[8] the object of study and its surrounding contexts, generating further questions and thicker understandings rather than seeking discreetly falsifiable answers.

4.1.1.1 Example: Walking Methods

One practice which inspired me from an ethnographic context was the use of walking methods. It is useful to mention it here both as a general touchstone and an example of the kind of methods which could emerge from this epistemology. Walking methods are a particular kind of staging where the researcher walks with the informant through a site relevant to the research, using the physical prompts of site to focus participant attention and reflection. Jon Anderson describes this as "the embodied art of walking through particular co-ingredient environments for recollection, in short: talking whilst walking"[9] (p. 259). He used this technique to collect interviews related to activist participation in the anti-road building movement in the UK in the 1990s. The interviews were conducted in the site in question, around ten years later. This provides the interviewees with a rich set of spatial and emotional cues for memory as well as a changed landscape against which to judge their feelings about the success of their actions. The embodied aspect of this approach is also important. By walking through the site, the interviewee is engaging with the space with the whole body rather than just as a mental abstraction. This allows a richer blend of interactions with and impressions of the site to be prompted and examined.

Anderson's use of 'talking whilst walking' uncovers memories around the site through embodied presence. Carpiano [10] has used a similar 'go-along' interview technique to investigate current public health concerns in a low income neighbourhood in Milwaukee, Wisconsin. He describes this technique as a combination of field observations and qualitative interviewing to explore "how social capital resources (e.g., economic, cultural, political, symbolic) that inhere within social network ties [are] nested within local community contexts and how community social capital was used (in positive and negative ways) for pursuing personal and collective goals" (p. 265). In other words, conducting interviews within the physical space in question is an excellent way to gain access to the complex overlapping social and experiential contexts which compose the lived experience of place in a particular site. By conducting the interviews within the spaces

themselves, Carpiano is able to gain more detailed and specific information about the way these contexts are constructed. These techniques stage experiments in ways that offer rich affective potential to catalyse participant reflection. Anderson and Carpiano ask participants to use both the surrounding environment and their own movement as cues for emotion and memory. In my own walking method I argue for a similar attention to staging using walking to elicit strong responses in participants.

As mentioned in the previous chapter, Tim Ingold argues that "walking down a city street is an intrinsically social activity" [11] (p.43). From this we can say that, in addition to situating the experiment in a particular site, walking, as a social activity, can be leveraged to explore social relations. In my case, rather than exploring purely social relations, I am interested in using walking to explore sociotechnical relations. The act of walking while checking a phone to see where one is going is a familiar example of such a relation. As discussed below, in my first method, the performance of this action is leveraged to emphasise an inversion in attention away from personal navigation and towards reflection on the presence of GNSS infrastructure.

Elsewhere, mobility and walking practices have been highly influential in the development of art and research practices and theory around GNSS [12–14]. In all these cases, the place where the research takes place is essential to the functioning of the method. One does not act upon the other, but rather the physical site combines with the act of walking and the researcher's interview to form one larger inventive method. The walking methods follow Lury and Wakeford's maxims [2] by creating addressability through their use of space and intervention through the re-framing of participants' lived experiences.

4.1.1.2 Accountability

In these walking methods, we can say that the researcher is strongly implicated in the staging of the research. In Law and Urry's words they "help to bring into being what they also discover"[5]. We therefore need to acknowledge the influence of all aspects of

the research situation to be accountable to these concerns and to build a more complete picture of the research process. In order to do this, I will make each staging and iteration of the research method explicit in this chapter. As I developed the work, I used thematic analysis techniques [15] to identify particular areas of concern. These informed the way I framed subsequent iterations of the research. In the analysis stage I use situational analysis techniques [16, 17] which incorporate research staging and attendant material actions and structural concerns into its conclusions. I chose this approach to be "accountable to the complexity"[16] (p. 559) I was producing both through the conscious staging of the research "in the wild"[18], and through the problematization of familiar technologies and practices. Situational analysis also offers steps towards an infrastructural inversion of the research process itself, allowing me to probe what is assumed both in attendant sociotechnical contexts and my own theoretical approaches.

Law claims that: "If we do want to think about more generous versions of method, we need to think seriously about methods that ignore the rules"[3] (p. 40). I enter this project, not aiming to break the rules, but rather to form experimental methods that can playfully and effectively probe and explore my area of concern by challenging accepted practices. I do this both from a research position of interdisciplinarity and in the spirit of Latour's argument that art practices offer a stronger degree of flexibility and freedom for thought experiments by being less beholden to disciplinary concerns [19]. The accountability built into the methods alongside this drive for freedom means that, despite its specificity, the research can have transferable value for colleagues in other areas. I also hope that, rather than pinning down particular facts and theories, the research process can uncover what is hidden, thereby generating engagement with the research which can engage with [2] and "enrich"[8] the object of study.

4.1.2 Practicalities

In each workshop, participants were given an android device with the open source android app *GPS Test* [20] installed. *GPS Test* draws on the information gathered by the device's

GNSS sensor to provide a visualisation of the presence and position of GNSS satellites in relation to the device. The app was designed as a utility to test GNSS coverage in a given area. In the research exercise this aspect of the design was exploited to allow participants to explore how different parts of a site interact with GNSS reception. As the resulting breakdowns are observed through the app, common uses of a GNSS-enabled device are defamiliarised and the infrastructure is pushed to the forefront. After walking for half an hour with this app, participants were asked to write and draw reflectively on their experience, then take part in a communal discussion which was recorded and later transcribed. The drawings, writings and discussion form the body of the research data.

4.1.3 Staging

Following some initial developmental experiments (described in subsequent sections), I began the main research process using this technique in April 2016 with a walking study at the Barbican Estate and Arts Centre in central London. The study did not take place as a formal collaboration with the Barbican, but was organised in association with a research organisation called The Capital Culture Exchange. A second walk took place in early June 2016, again at the Barbican and in association with another research organisation called Antiuniversity Now. A third took place in July 2016 at the Barbican and was self-organised. The final workshop took place in association with the Loitering with Intent exhibition at Manchester People's History Museum in August 2016. It broke with the other workshops by using a different location, taking in a city centre walk beginning in a newly redeveloped canalside area of Manchester. In the following subsections, I will describe the influence of choices around physical site, participant profile, technical equipment and development and iteration.

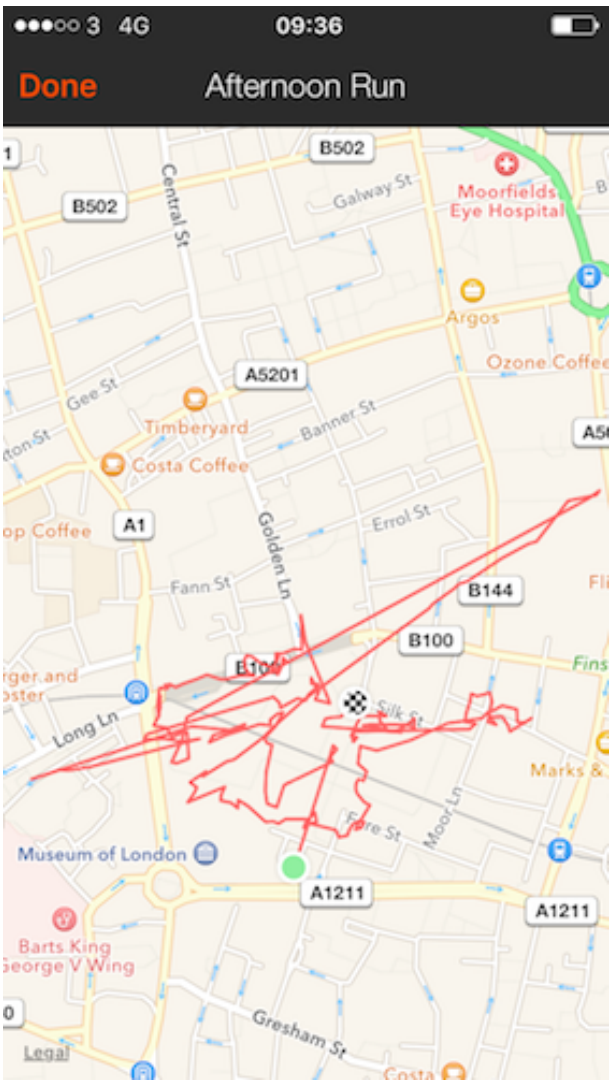

Figure 4.1: A walk taken through the Barbican rendered on the *Strava* running app. There are several points where inaccuracies in GNSS reception lead to a jump in the device's understood position, visible as straight lines leading outside the central area.

4.1.3.1 Site

The Barbican Estate was chosen as the primary site for this research primarily because of the destabilising effect it has on GNSS reception. I was very familiar with the estate having spent several years working there as an architectural tour guide. The estate was built between 1962 and 1974 with a large art and conference centre incorporated into the design midway through this process. Architecturally, the estate is a striking

Figure 4.2: A participant moves through the Barbican Estate.

example of British brutalism with around the half the structures built in sheer concrete. The presence of multiple covered walkways and areas in the shadow of large buildings leads to blocks in the transmission of GNSS signals. I tested the effectiveness of GNSS reception on the estate by carrying a mobile phone running *Strava*, an app designed to record exercise routes, while conducting architecture tours. The tours followed a slow walking pace with plenty of stops in different places, thereby reflecting the type of mobility I would expect a participant to take on the research exercise. The resulting map showed several jumps in position as GNSS accuracy was impeded by blocked lines of sight with the sky or thrown off by multipath errors as GNSS signals were reflected off buildings, adding a delay and rendering the signal's timestamp less accurate. In the above figure (4.1), the majority of the walk is recorded within the Barbican Estate, but several jumps occur (visible as long straight lines) to locations several hundred metres from the

estate. From these experiments, I concluded that the Barbican would be an effective site in causing breakdown and malfunction in the operation of GNSS infrastructure and, thereby, contribute to a sense of infrastructural inversion for the participant.

It is also worth noting that, through an association with art (through the presence of the arts centre) and architecture (through the famous and striking design of the site), the use of the Barbican helped to situate this work within an arts context for participants. The workshop was self-described as an art-research experience. This was a tactical choice both to situate my own work within a history of locative media art and provide something enticing to potential participants. This made the activity more attractive to both the partner organisations and the participants they would bring in through their networks.

The final study was based in Manchester's People's History Museum. The People's History Museum is set in a recently constructed glass and steel building surrounded by similar redevelopments. It is a short walk from the Victorian and 20th Century buildings in the city centre. The decision to stage the walk here was based partly on the availability of partner organisation, but it also offered an interesting architectural counterpoint to the use of the Barbican. In this walk, the set up worked in a slightly different way. Because the site was less contained, the walk was semi-structured with the group moving between prearranged points. This made sure we covered broadly the same areas and allowed me to improvise the walk, directing participants to areas which I guessed would provide blocking or multipath errors for GNSS reception. I had a morning in Manchester before the walk to scout possible locations, but during the walk I was open to suggestions from local participants as they began to observe how GNSS reception was effected by different buildings. Over the course of the walk we stopped in the shadow of recently built glass towers, narrow Victorian alleys with limited visibility to the sky, the corn exchange, a vast Victorian trading hall with a glass domed roof recently converted into a theatre, and the Arndale Centre, a mid-20th Century shopping mall with multiple levels and some skylights providing a line of sight to the sky. These participants, therefore, got a much broader range of built environments through which to understand the presence of

GNSS infrastructure. The successes and failures of this shift are considered below in the iteration section.

4.1.3.2 Participants and partner organisations

Over the course of four research experiments I worked with 26 participants, the majority of whom identified as artists or researchers. Three out of the four walks were conducted in association with various art and research organisations. The choice to work with such groups was partly formed my own experience of submitting to open calls for work. I had spent a lot of time doing this as a practicing artist, and wanted to continue to situate the work in an arts context. This approach was also a tactical choice to get access to potential participants. By partnering with such organisations, I would gain access to a wider network of potential respondents allowing me to expand my circle beyond friends and colleagues. The profile of the organisations also matched my chosen participant profile of artists and researchers. From my preliminary experiments, I had decided that these were the groups I wanted to concentrate on because of their openness to different conceptual approaches.

The first research organisation I worked with was The Culture Capital Exchange (TCCE), a cross-institutional academic organisation which focuses on "knowledge exchange, collaboration and wider engagement between the research base and the arts"[21]. I received nine participants for this walk, most of whom identified as researchers, artists or designers.

Antiuniversity Now, the second organisation, are inspired by the experiments in radical education which took place in London in the late 1960s. They aim to challenge existing structures of knowledge production "by inviting people to organise and share free learning events in public spaces"[22]. For this experiment I received six participants, two artists, two researchers, one designer and one who worked for a company that supported small businesses.

The third Barbican walk took place without a partner organisation, more because one wasn't available than through choice. For this walk I received four participants who I recruited via my own networks. Of the participants, one was an artist, two were researchers and one was a journalist.

The final partner organisation was the *Loitering with Intent* exhibition at Manchester's People's History Museum. I had responded to an open call put out by the curators for workshops for the exhibit. This research experiment, therefore, took place firmly within an arts and museum context. Because it took place in an unfamiliar city, my own networks for participant recruitment were not useful, meaning I was totally reliant on the museum and the curators. I received seven participants, although one had to leave before the data collection stage. The participant group was more diverse than previous ones, with two researchers, one of whom also identified as an artist, one metalworker who also identified as an artist, one web developer and one manager in a telecommunications company. Perhaps because of this more diverse group, the discussion was broader and less focused than in previous experiments. This will be discussed in more detail in the iteration section below.

4.1.3.3 Technical Equipment

The participants were given *GPS Test*, the open source app developed by Chartcross [20] and described above which uses the affordances allowed by the Android operating system to plot a compass-style map of GNSS satellite positions in relation to the device. The app also offers a bar chart of relative signal to noise ratios for transmissions from the satellites in view and information relating to the device's velocity and height relative to sea level. Figure 4.3 shows two screens from *GPS Test*, one with a compass-style view identifying GPS satellites by their PRN numbers, the other comparing their signal-to-noise ratios. These screenshots were taken on one side of an apartment building where the sky (and satellites) to the east is clear, but the view to the west is blocked.

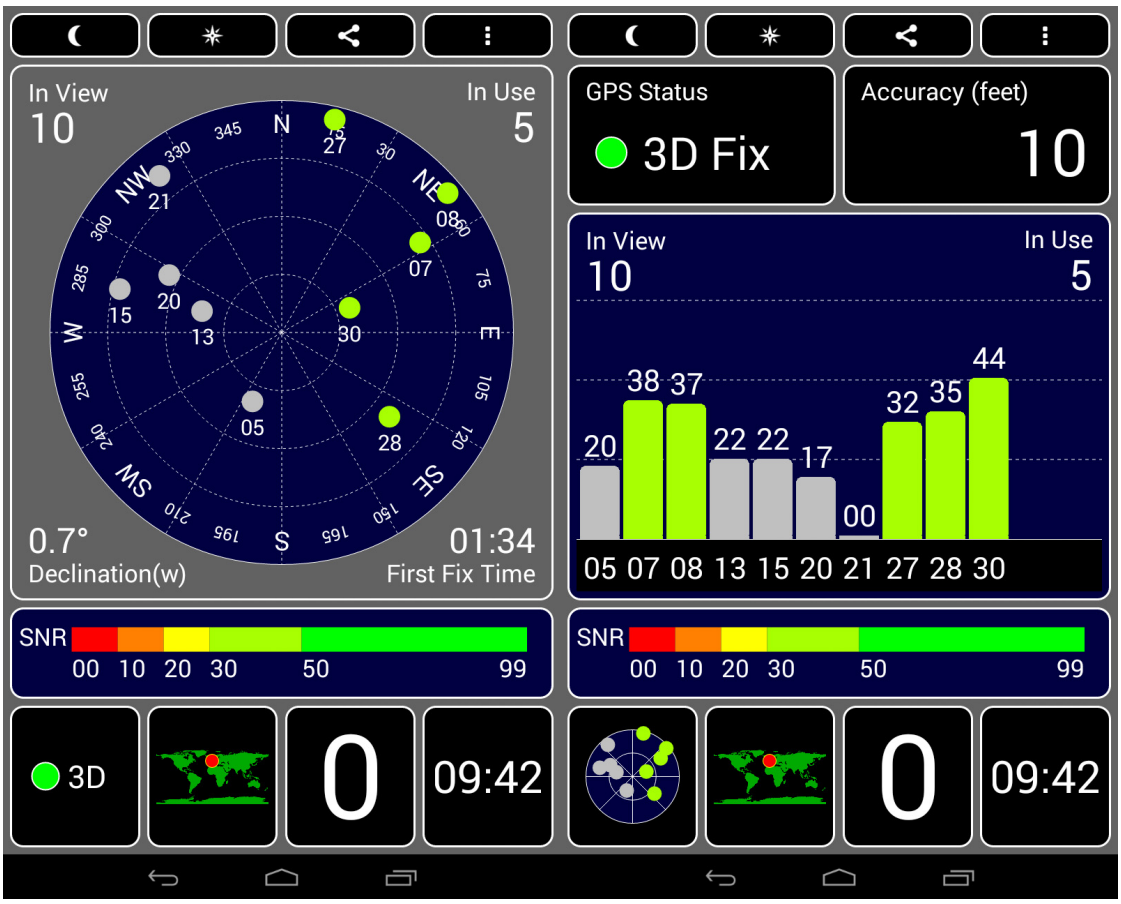

Figure 4.3: *GPS Test* app developed by Chartcross.

To give the participants some idea what they were seeing on the app, I also gave them a brief explanation of the way location is established through the triangulation of time-stamped satellite signals and compared to the known trajectories of individual satellites within an almanac database. The participants were given Yuntab K03-7 7-inch tablet devices running the Android 4.2 operating system and *GPS Test*. In some cases the participants preferred to use their own Android devices. This was also the case when the number of participants exceeded the number of Yuntab devices available. In these cases, participants noticed some differentiation between hardware. The Yuntab devices are cheap and basic devices with a low hardware specification. On other devices, the app was able to load and run faster. Other devices with different sensors and more recent versions of the Android OS could also receive signals from the Russian GLONASS network. These satellites were depicted on *GPS Test*'s visualisation as triangles. At the

time of writing later versions of the Android OS and *GPS Test* have appeared which can also visualise satellites from other GNSS networks, but none of our participants used a *GPS Test* version with these abilities.

By using a device as familiar as a tablet or cellphone, the experiment worked to defamiliarise existing sociotechnical practices in a radical and direct way. If the participants had been given a dedicated GNSS-enabled device or one which had been protyped specifically for their research then the connection with their usual practices would have been weaker. The use of the tablet or cellphone as an object is also important in considering the staging of the research. The use of such a familiar object, as well as being an easy, off-the-shelf research tool, was intended to add to the sense of detournment and defamiliarisation created by the research experience.

4.1.4 Analysis Techniques

In this subsection I consider the analysis techniques used to approach the data from this study. I coded as I went along, using grounded theory to [15] identify themes used in the iteration of the workshops and, later, situational analysis [16] to arrange the themes and interrogate them by incorporating my own staging and the material, technical and environmental elements of the site.

The 'raw' data from the walk was twofold. I used the individual writing and drawing which participants completed after their walk. I also recorded and transcribed the discussion. Practically speaking, the content in the discussion and individual work contained some overlap. In the analysis, where there was a clear duplicate, I coded initially from the discussion but drew on the individual work to give a richer account of the participants thoughts as required by later iterations. In both cases I paid particular attention to the use of metaphor to get a sense of the "texture" [1] of the infrastructure's actions.

The pictures drawn by participants were also important. Drawing techniques "allow us to access and represent different levels of experience"[23] (p. 547). However, while

Bagnoli uses narrative analysis to produce a gestalt picture of the participants from drawing and interview, here I use the drawing primarily as a mode of elicitation and to accelerate participant reflection in advance of the discussion. In this way, the content of the drawings were considered reflective of themes which emerged elsewhere. In some instances, the pictures provided particularly strong representations of themes and these have been included here as figures. On a practical note, I found that the use of drawings was particularly effective in conveying spatial concerns, numerous drawings placed the participant in relation to both buildings and satellites.

Using MAXQDA software I identified themes after each experiment, then reconsidered them after subsequent data had been added later. A constructivist-influenced iteration of the Straussian approach to grounded theory [15, 16, 24] was chosen because of the way in which it allows prior theoretical and professional experience to feed into the analysis. This was considered important because the work was taking place surrounded by numerous uncertainties. The research is situated in a complex, interdisciplinary setting where particular theoretical approaches have to be negotiated. The experimental nature of the research method was also a concern, and, by allowing the experience gained from my own art practice, running workshops in art and education contexts, and knowledge of the Barbican to inform each iteration of the research, the process could develop more smoothly.

With each iteration, themes were reconsidered, re-aggregated and split into new structures. At the end of the four workshops I added these themes to a situational analysis. Situational analysis was proposed by Clarke [16, 17] who wanted to move beyond the conditional matrices proposed by Strauss and Corbin to "lay out the major human, nonhuman, discursive, and other elements in the research situation of concern and provoke analyses of relations among them"[16] (p. 559). Through iteration, the map develops from a messy to a cleaner form, making a continual work-in-progress system which we can ask questions of. The map produced by situational analysis is not a finished analytic product, but displays a set of relations which are complex and dynamic. It reaches

usability at the point of data saturation. Through a multi-levelled interrogation, situational analysis emphasises the importance of interrogating codes from multiple angles [25], focussing on their interactions and emergence. It provides a way to be accountable to the iteration and development of codes alongside repeated experiments.

In spirit, situational analysis is similar to infrastructural inversion. By allowing the "silent spaces" produced by theoretical assumptions to be mapped alongside participant responses, it critiques the way the research process creates knowledge, bringing hidden, accepted research conventions into view. Clarke acknowledges the similarities with infrastructural inversion, calling her own method a kind of "social inversion"[16] (p. 572). This is particularly important in this research where the concerns of the researcher are given presence by the construction of the experiment, through technique, staging and site. Situational analysis creates a way to be "accountable to the complexity"[16] of this process.

Through its inclusion of nonhuman and discursive elements into analysis, Clarke's approach also resonates with Karen Barad's theory of intra-action [26, 27]. For Barad, agency emerges across a network of human and non-human elements. We cannot say that one thing causes another, but rather that agency emerges across a network of factors and concerns. I consider this theory to be particularly useful in the discussion of infrastructure as it allows for the formative influence of non-human factors in our sociotechnical practices. Situational analysis allows room to invite these factors into the treatment of data, giving agency a resonance that reaches beyond the participant and the researcher.

Situational analysis also speaks to the understanding of method offered by Lury and Wakeford [2] and John Law [3] at the start of this chapter. For Lury and Wakeford, the specificity of inventive methods is an area of note. Situational analysis allows the specificities of the research framing and situation to come into play at the analysis as well as the planning stage. For Law, method is understood as a way of "hold[ing] [realities] steady for a moment against a background of flux and indeterminacy"[3] (p. 10).

Situational analysis acknowledges the dynamism of the research situation, emerging as an iterative work in progress, incorporating flux and indeterminacy rather than denying or trying to eliminate it.

4.1.5 Development and Iteration

The method developed here was experimental and iterative. I spent some time developing it through early experiments and then tuning it through subsequent workshops. In so doing, I was following the epistemological guidelines set out by Lury and Wakeford [2] to iterate the methods until they can achieve "answerability" for the problem area. Again, following Law [3], I wanted to "hold these realities in place for a moment" to understand how the reality created by the experiment challenged the emergence of standard practices and offered alternatives. This required reflective awareness of the research process and the types of reality it created. Effort was needed to be made to make these realities relevant to the area of study.

In this section I describe a series of initial experiments and the key points I drew from them. A description of these experiments is included for completeness and accountability. Once the method became more stable I began to use it in the studies in the Barbican. Subsequently, after initial themes began to emerge, I tuned it further to focus in on specific themes. An account of this development and iteration process follows.

4.1.5.1 Initial Experiments

The first experiment using this technique took place before any of the Barbican workshops, on the Multimaderia artists' residency in Funchal, Madeira, Portugal in February 2016. I describe this development workshop here for completeness and to emphasise the efforts made to give the method addressability to the research questions. In this first test, following a brief technical introduction in which I explained how the devices established a GNSS fix, the group of five participants (all artists on the residency) were

asked to explore the streets of Funchal using both *GPS Test* and the *Strava* exercise app that I had used to map the Barbican. *Strava* uses a map to plot the route taken by the participant. As in the Barbican experiment, its use was intended to display moments of inaccuracy through sudden jumps that the recorded route would make when a signal became inaccurate or lost. None of the artists were from Funchal (rather hailing from Switzerland, Germany, the UK and Serbia) and none had been there longer than two weeks. As a result, they were, at best, passingly familiar with the city. After around half an hour of free movement, participants returned to the workshop space, drew and wrote in response to the experience then had a group discussion. In this workshop therefore, the main format matched later iterations of the workshop, but the use of *Strava* alongside *GPS Test* was a major difference.

The workshop produced some promising early data concerning participants' relationships with infrastructure, particularly around ideas of visibility from the sky and the influence of architecture. While these outcomes were promising, it was noted that three out of five participants used the drawing exercise to copy the map created by the *Strava* running app (see figure 4.4). This provided an early indication of how influential the visualisations produced by the apps could be. From this experience, I decided that *Strava* was too deterministic in influencing participant responses, with the map providing too obvious a visual reference point. I therefore dropped *Strava* from subsequent iterations of the workshop and concentrated on the use of *GPS Test*.

A month later I conducted another experiment in Sweden as part of the Nordic Summer School: Circle 6 (Appropriating Science and Technology for Societal Change)'s winter meeting at an arts centre in a disused paper mill in rual Sweden (see figure 4.5). The presentation of this workshop was slightly different from the one conducted in Madeira. It was shorter and also sought to address some of the speculative design concerns which would later become an important part of this research. The meeting was themed around a confluence of DIY technologists and people involved in DIY permaculture and community building. It asked how such a confluence could create useful

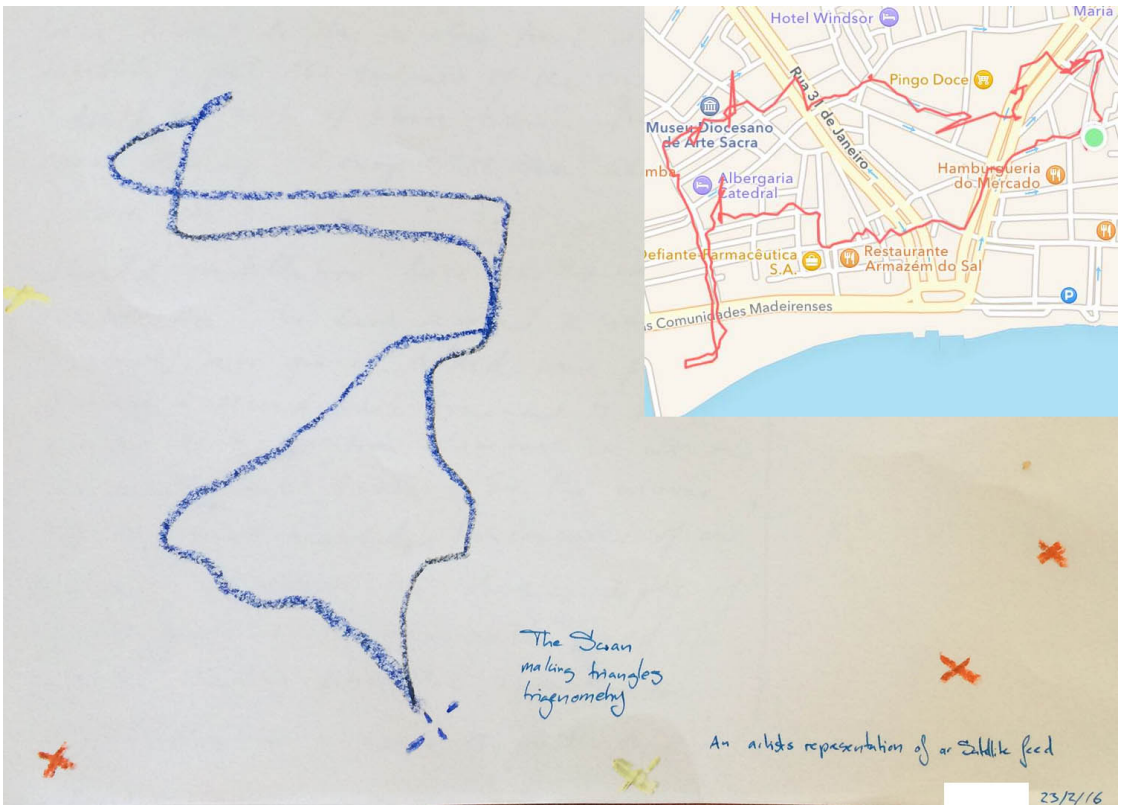

Figure 4.4: Participant drawing from the Madeira workshop with inset image from *Strava* showing a strong similarity

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applications as the world shifts into the anthropocene and catastrophic climate change begins to put stress on social and technical practices. My workshop offered a re-framing of GNSS technology, imagining how the infrastructure could work stripped of its usual sociotechnical practices in a world riven by social and environmental collapse. What possible ways could we relate to GNSS in such a situation? I will refer back to this preliminary study later when I describe the speculative design-focussed method, but I include it here because of the elements it shares with other walking workshops.

The makeup of the sample group was varied, with just over half the participants from a technical or computer science background. The other permaculture and DIY-community group also had some experience of using GNSS via commercial applications (and one participant also frequently used GNSS co-ordinates to log the position of rare plant species). The more technically minded group already had a clear idea of how the

Figure 4.5: Participants move around a former mill in Fengersfors, Sweden.

infrastructure should function (or at least thought they did) and therefore experienced moments of breakdown as technical hitches rather than a shift in understanding their own practices. For the other group, the prompts were received in more conceptual terms, but did not always produce rich data. One wrote that at moments of breakdown, "the device is confused and the satellites didn't care". Other participants were more engaged by the speculative aspects of the prompt and a discussion of those responses can be found later in this chapter.

The lessons I took from the experiment in Sweden were not to overload the workshop with too many prompts, questions and activities. Specifically, I decided that the two methods (walking and speculative design) were distinct and should not be offered to participants at the same time. There was a real danger here that participants could get lost in the potential avenues the experiment could take.

Drawing on my experiences in both Madeira and Sweden I decided that I would aim the walking method at artists and researchers rather than engineers and those with a technical background. The method used was quite concrete, in the sense that it uncovered traceable interactions which were present but concealed. If the participant already had a semi-working knowledge of how the infrastructure does or might work, then the moment of revelation, where poetic methods are used to challenge and defamiliarise sociotechnical practices is lost. I decided that the moment where the infrastructure is inverted or revealed is key in the method. It is this shift that catalyses the research process. As such, the method is much more effective when the reveal is tangible, when it actively challenges existing knowledge and practices. Artists and researchers generally (though not always!) have a lower level of technical knowledge than engineers and computer scientists. From these experiences, I could say that artists and researchers were generally more sympathetic to the conceptual orientation of this method. They were therefore more likely to respond to the method's prompts with rich data. In the main walking studies, therefore, I aimed to orient participation towards a demographic of artists and researchers.

4.1.5.2 Iterations

Throughout the four workshops some shifts in framing took place, not least with the shift in site from London to Manchester. To hold these iterations to account, in this subsection I briefly describe these changes, what concerns and changes in circumstance provoked them, and how successful I would judge them to be. More detail is given in the findings chapter. The lessons learned from these iterations, as well as holding my own research to account, may be useful to other researchers working through similar concerns.

A key shift took place in the third and fourth workshops (the self-organised one in the Barbican and the one in Manchester). Here I asked the participants to concentrate on specific themes which had emerged in analysing the first two workshops. The workflow

of the experiment was the same, except in the pre-walk introduction I asked participants to pay particular attention to any thoughts they had on the given theme. The themes were; surveillance and privacy in the third workshop, and architecture in the fourth. This choice was made as a way of probing deeper into consistent areas of concern. As it turned out, this shift in focus enjoyed mixed success. The theme of surveillance and privacy produced useful, deep and detailed reflections on the participants' sociotechnical practices, while the focus on architecture in Manchester was less successful. Although some interesting thoughts emerged here, the discussion began to ramble into other areas despite several unsuccessful attempts to steer it back to the proposed theme. Ironically, surveillance and privacy emerged as a very strong theme in the Manchester discussion as did locative gaming applications, perhaps influenced by the recent release and press coverage of the *Pokemon Go* game. In this way, I note that several things were at play in the iteration of the research method. The iteration did not take place within a controlled environment, shifts in the media and cultural landscape may also have a strong effect on emergent themes. I hold these to account through my use of situational analysis on the collected data from all four workshops.

Another small iteration to note is that, after the first Barbican workshop, I made the decision to let participants keep the drawn and written material they produced. In this first Barbican and preliminary workshops I had kept the materials that participants produced. However, I received some feedback that the exchange between researcher and participant was imbalanced, and that, although I had provided some technical knowledge about how GNSS worked, I had taken everything from them to fuel my research in a way that was described as 'vampiric'. As a result I changed my practice for the workshop organised by Antiuniversity Now and, also informed by their commitment to radically free and open education, I decided not to take the drawn and written materials back to the university. Instead I took pictures of what they produced on site. The sacrifice I made here was losing the ability to create high quality scans of those writing and drawings. However, it felt fairer to leave participants with some record of the experiment, even if

they forgot about it long before I finished my work on the topic.

4.1.6 Limitations

The aim of this workshop was to make the operation of GNSS infrastructure and its material agency more visible, thereby challenging existing sociotechnical practices. While the method achieved this in part, it also added its own colouring to interactions in the research process. By replacing usual GNSS-driven interfaces with another interface it arguably created a different filter on participants' experience. In this way, it did not so much remove the blackbox, but replace it with a different type of 'grayer' box. The presence of this 'greybox' means that the data that was created through this workshop may be in danger of being overly determined by the research tools.

One way of understanding the characteristics of this greybox is through the emphasis which is given to satellites as opposed to any other part of the GNSS infrastructure. The ground aspect of GNSS is equally significant and, perhaps, easier to understand as politically active, however, this aspect was not open to immediate consideration in the research staging. *GPS Test* focuses on the presence of satellites overhead and how that presence can be established in concert with surrounding environmental factors. This does represent a significant shift away from the invisibility of infrastructure in everyday practices, but it is not the complete story. The specific organisation and politics of GNSS ground elements would offer a compelling alternative research process, one that would benefit from further work in the future. These limitations and what they mean for the transferability of the research method are considered in more detail in the discussion chapter.

4.2 Design Method

The first method described above explored how people's conception of their sociotechnical practices shifted when attention was focussed on the underlying infrastructure. The second poetic method, described here, asked what happens when I try and shift wider ontological understandings by emphasising the agency of the underlying infrastructure. I do this by creating speculative future scenarios in which the roles of GNSS infrastructure become more prominent. The scenarios offer fictive alternative worlds that de-emphasise the importance of the human user and emphasise the material agency of GNSS. To make this conceptual leap I chose to work with speculative design. This technique allowed me to give participants a strong conceptual frame through the proposition of a future scenario. This allows the work to not only critique of the power asymmetries produced by blackboxing (a feature it shares with the previous method), but also create a space to think through future situations where technological shifts will, echoing Barad [26, 27], re-construct how users' and infrastructure's agency is understood.

Again, metaphor plays a strong role in the data collected from the experiment. The data here is a series of fictive objects or scenarios which exist within the wider speculative brief. These metaphors are powerful tools to diagnose the way the relative agencies of user and infrastructure are currently understood and to provide space to propose alternatives. In this way they address my second two research questions concerning whether this shift in attention can indeed change understandings around the centrality of the user and the nature of more-than-human networks.

This section is organised in a similar way to the first half of this chapter. I begin by grounding my use of speculative design in the context of related approaches within design and HCI. I then describe some of workshop practicalities including participant selection, the materials given to participants and the data collection and analysis techniques. I go on to describe the initial experiments which led to the experiment design and a description of how the workshop developed over several iterations. I conclude by

describing some limitations of the method.

4.2.1 Epistemology

My use of speculative design is intended to, through the creative process, produce understanding of how infrastructures can be re-framed as holding active agency in the formation of sociotechnical practices. As such, this technique explores what happens when the importance of the user is pushed further into the background. In this scenario, we can go on to ask how the material agency of infrastructures is re-understood and how this effects the ontological boundaries that separate user and infrastructure. In this way the research process can be understood as introducing complexity as much as introducing clarity. Speculative design is used to generate deeper engagement with the ways infrastructures presently do and alternatively could form diverse alternative practices and relations. The method seeks to make problems as much as to answer them. In so doing it works at the boundaries and overlaps between STS, HCI and design, aiming to create a space where these disciplines can interplay successfully.

The understandings and problems produced were intended to be both diagnostic and pedagogic. For myself, as the researcher, the diagnostic understandings would help me to develop analysis. Their success would be measured by their 'addressability' to the research questions. I also wanted to produce pedagogic outcomes where participants would have their assumptions challenged and come away from the experience feeling like they either knew more than before or had a fresh perspective on the research area. This aspect was evaluated directly in the post-workshop discussion and through questionnaires distributed at the end of the session.

Interdisciplinary sociologist Mike Michael also argues for design to undertake enrichment through problem forming. Specifically, he seeks the formation of publics which "are diffuse, and their politics are less discrete and more circuitous. They are not focused on specific issues, nor targeted at identifiable stakeholders, but oriented toward

the exploration of the complexity of the "issues" and the process of inventive problem making"[28] (p. 542 – 3). This "inventive problem making" is a way of thinking through emergent publics which do not just contain human users, but also technical objects and processes. It speaks to emergent assemblages, publics, objects and scenarios. For designer Tom Jenkins these are "Object-Oriented Publics"[29] and, while Jenkins' work focuses more on participatory and co-design projects, I would suggest that the idea of an object-oriented public is a useful tool in looking forward to the future overlapping concerns of human and nonhuman agents. This re-alignment to incorporate non-human actants provides a way of thinking through conceptually obscure or emergent concerns.

There is, however, some debate about the relationship between ideas of emergent assemblage and design practice. In the same paper, Jenkins argues, regarding actor-network theory, that:

> "ANT is useful for analyzing networks that already exist. Unfortunately, it is not a perspective that is well equipped for conceptualizing and generating networks (or products, or services) that do not yet exist"[29] (p. 829).

While this bold statement should be read primarily in the context of the authors' participatory and co-design work, as far as this understanding relates to my work, I would disagree with Jenkins. My second, design-driven method aims to offer new conceptualisations and a different way of thinking through doing [30]. These new understandings of GNSS do, I argue, form new kinds of networks through poetic interventions and reframings. At the same time, they also allow the interrogation of present concerns through these alternatives.

It is worth noting that across both the walking and design methods, the research continues to face human participants. I wanted to keep the focus on the ways in which human-led (if not centred) research methods can make sense of a shift in understanding sociotechnical practices and assemblages. This emerges from an interest in rethinking what such shifts might mean conceptually, where the formation of such concepts, while

being open to other forms, remains a human concern. It is also worth noting that there is a submerged aim here that this research may help people to rethink and reorient their position in relation to existing sociotechnical assemblages and prepare for ones which may emerge in the future. So, while not explicitly engaged in a practice of co-design, the work does draw on the pedagogic drive of Matt Ratto's critical making project [30].

In using design methods, I am also interested in their potential to create different forms of familiar concepts or situations. Creativity is transformative in both a personal and broader sense in that, through an "interaction between a person's thoughts and a sociocultural context the symbolic domain in the culture is changed."[31]. For Law and Urry, method at large is understood as a generative process. When we accept this, the shift means that are "no longer different perspectives on a single reality, they become instead the enactment of different realities"[5]. This something that I recognise and embrace in my own use of methods. The incorporation of design-driven methods allows a greater potential for methods to be generative as well as descriptive, producing a richer diagnosis by generating new perspectives from which to see the research area.

As described in the previous chapter, speculative design has emerged alongside several other design approaches which also carry a critical spirit and deal with authorly concerns. Reflective design as proposed by Sengers et al argues that "design practices should support both designers and users in ongoing critical reflection about technology and its relationship to human life"[32]. Here, reflection is a generative as well as descriptive process:

"Critical reflection itself can and should be a core principle of technology design for identifying blind spots and opening new design spaces. We argue that ongoing reflection by both users and designers is a crucial element of a socially responsible technology design practice" (p. 49).

This process is as much about inspiring new formations as describing what is already there, while the first method "identified blind spots", the second method aims to open

"new design spaces".

The method described here also draws inspiration from Gaver's formulation of research-by-design through his call to produce process-driven "provisional, contingent and aspirational theory"[33], particularly in response to wicked problems which defy easy containment, framing or categorisation. As Dunne and Raby also note [34], such problems may force us to change the kinds of world we create through our actions. This concern is relevant for research methods as much as design briefs. Following Law and Urry's thoughts about how methods generate multiple worlds and realities [5], Gaver argues that research is concerned with ontological formation as much as epistemology and that research-by-design is explicitly:

> "a generative discipline, able to create multiple new worlds rather than describing a single existing one. Its practitioners may share many assumptions about how to pursue it, but equally, they may build as many incompatible worlds as they wish to live in"[33] (p. 943).

The ontological understanding proposed by Gaver applies principally to the creation of design objects such as his own influential 'Drift Table' [35]. My own method also follows Gaver's drive for open-ended reflection, but I am less concerned with producing design objects and more interested in the ways in which the design process can act as an exploratory form of "inventive problem making"[28]. The creation of these "new worlds" can offer new and richer perspectives to the problem area while also pointing to a process of 'thinking through' a problem area that can perform a pedagogic role. To explore this in more detail I turn to Ratto's proposal for critical making [30].

Ratto aligns critical making with critical [36] and reflective [32] design approaches through its "emphasis on critique and expression rather than technical sophistication and function"[30] (p. 253). However, there is a shift that takes place in critical making which I echo in this project:

> "Critical making emphasizes the shared acts of making rather than the

> evocative object. The final prototypes are not intended to be displayed and to speak for themselves. Instead, they are considered a means to an end, and achieve value though the act of shared construction, joint conversation, and reflection" (p. 253).

To emphasise, the areas of concern are broadly similar; Ratto explicitly shares an interest in 'wicked problems' and allies his work with critical and reflective design, but he argues for design workshops which focus on process rather than a finished object, using this as a way to introduce a constructivist pedagogy. This can allow participants to better think through social and conceptual issues by using "material production making things as part of an explicit practice of concept elaboration within the social study of technology" [30] (p. 252). I would understand this concept elaboration, following Asdal and Moser, as an allied means to "enrich rather than reduce" the object of study [8]. By thickening conceptual understandings around material technologies, the workshop process can transform those technologies from firm and fixed "matters of fact" to being discursive and emergent "matters of concern" [30, 37]. In offering research as a way to "deepen conceptual understandings"[30] (p. 259), Ratto is able to draw deeper forms of engagement from participants. In this he follows Daniel Fallman [38] in distinguishing between "design-oriented-research" rather than "research-oriented-design', situating himself in the former category.

Critical making has been influential in forming both the methods I propose here. In the first, walking method its influence is more submerged, and concerns the pedagogic aspects of the workshop enacted by pushing against the material limits of a technology. In this way, the method functioned as an exploration of the material limits and operations of GNSS technology. In the second, design-driven technique, critical making is more influential in terms of form. The speculative design workshops described here are understood acts of collective making intended to deepen conceptual understanding of locative technologies. As in critical making, the prototypes which emerge at the end are not the most important part of the workshop, rather I am interested in the diagnostic

and pedagogic discourses which emerge though the design process.

It is worth noting that my own work marks a development or iteration of critical making in which material exploration is less important. I argue that ontological or epistemological exploration is also possible, using symbol and metaphor as tools and building blocks. To re-iterate, in another innovation, this time on speculative design, the workshops I propose emphasise an ongoing emergent discursive process as the aim of the work rather than a meticulously crafted artefact or scenario is the focus of the work [34].

4.2.2 Practicalities

Here I describe the design workshops in practical terms. After some initial experiments and development (described below) I set upon a workshop template. Participants were asked to form groups of two or three and were given a future scenario. Their job was to develop a specific sub-scenario (understood as a set of interactions or an object) which could exist within this future world. They had around an hour to develop their project after which time they were asked to present it to the group. Following the presentations the participants gathered for a discussion about their experience of the workshop and the themes which emerged. The participants' project presentations and the discussion formed the research data.

The analysis stage was similar to the previous workshop: the data was organised into themes using grounded theory principles then fed into a situational analysis which also included the research staging, my theoretical assumptions and participant profiles. I then addressed my research questions to the situational analysis, asking how understandings shifted around the user and more-than-human networks. As we shall see in subsequent chapters, the ability of the method to access this area of interest also became a key focus for discussion.

4.2.3 Participants

In my key developmental workshop the participant profile weighed heavily towards designers with some researchers and artists. This was a result of a combination of the partner organisation and the engagement made with design schools. The choice to focus on this demographic was influenced by the experience of the walking workshops in which artists and researchers had proved more willing and able than those from an engineering background to engage with conceptual approaches which challenged familiar practices. However, after this initial experiment, I felt that a lack of technical understanding acted as a hindrance to my research goals. In the designs proposed by participants, the workings of GNSS got lost, replaced by conceptual understandings which veer too far away from the material limits emphasised by Ratto [30]. Because of this, the research aim of foregrounding infrastructure over the user's intentions and desires receded into the background.

In response, I changed the participant group, choosing to also work with people from a engineering background and, in particular, participants with a developed technical understanding of GNSS infrastructure. Their experience would implicitly emphasise the infrastructure's present material limits before offering ways in which future scenarios could surpass them. The outcomes of the developmental study were still considered relevant and are described in brief in the findings chapter, however, in analysis more weight is given to the workshops that followed.

The next round of workshops took place at Queen Mary University of London. I ran two evening workshops with engineers. These were principally colleagues from the Electronic Engineering and Computer Science department at Queen Mary, but, through my networks, I recruited two engineers who worked specifically with GNSS. One worked for Airbus in developing the Galileo system, the other specialised in satellite antennas. There was, therefore, one satellite specialist in each set of workshops. The effects of this shift are described in detail in the findings chapter, but participants did report that

the presence of these specialists kept their ideas relatively grounded, with the engineers advising whether certain scenarios were reasonable within the technical boundaries set by the GNSS system.

Following the developmental workshop I also changed the scenario in an effort to further emphasise the material agency of infrastructure. I therefore organised another workshop using this second brief with a group of professional designers at Future Cities Catapult, a government-funded research organisation and 'innovation hub' based in London. This additional group allowed me to iterate the designer group, using the same prompt and professional designers. In contrast to the design students used the earlier workshop iteration, the Future Cities Catapult designers had experience with the technical practicalities of locative projects within urban contexts. With this professional background they were well suited to explore the themes borne out by this scenario, with their training providing an interesting counterpoint to the engineers in the previous workshop.

4.2.3.1 Technical Equipment

An important part of the workshop was the creation of an artefact which represents the scenario developed by participants. This 'paper prototype' was used to focus each group's thinking and help them communicate their concept to other participants. To build the artefact, I provided each workshop with a set of craft materials. These were quite basic and included coloured pens, paper, glue, sellotape, and aluminium foil. There were no limitations put on what kind of artefact could be produced; they were not intended to be early iterations of a future product or service, rather they were a discursive tool to focus thinking and facilitate communication.

4.2.4 Analysis Techniques

I used situational analysis to consider the outcomes of each round of workshops in turn. To achieve the analysis, I incorporated the brief, location and staging of each design as well as the participant group and their background knowledge. The reflective discussion at the end of each session also provided useful meta-codes with which to approach the staging of each workshop. The results of these situational analyses are described in detail in the findings chapter. Finally, to make sense of the method as a whole, I made a further analysis considering all the codes produced by this method together. While doing this analysis I remained open to the possibility that certain codes had shifted, given the addition of new information. The final analysis is considered at the end of my findings chapter and then feeds into the theoretical and methodological work in the discussion chapter.

4.2.5 Development and Iteration

Below, I describe in brief an initial experiment in speculative design undertaken in Sweden. This activity has already been mentioned in relation to the walking method, but is also included here because it contained early experiments in speculative scenarios. I go on to describe the iteration of this technique through a series of design workshops in London. These comprise one developmental workshop and two subsequent workshops with a different scenario and participant groups. I emphasise that, because of a shift in scenario and participants after the developmental workshop, the majority of research data for this technique is taken from the subsequent two workshops. An account of the developmental workshop is also included in brief in the findings section for the sake of completeness and to contribute to a discussion of method.

4.2.5.1 Initial Experiments

At the workshop in Sweden described in the first half of this chapter, I mixed the walking and design methods, encouraging participants to either respond to the walking experiment or use it as inspiration for a speculative design prompt. Following the responses described in the first half of this chapter, I felt that this approach was too open to produce useful material. I therefore made the choice to separate out the walking and design methods into separate workshops.

The brief I gave to the participants in this early workshop was to imagine a dystopian future world, after social and environmental collapse, where existing uses of GNSS satellites no longer applied. How might the satellites continue to function in such a world and what relationship might we have with them? I was encouraged to continue using speculative techniques by one response which contained a series of drawings of people and animals engaging in new ways with GNSS signals. In the drawings, a priesthood builds shrines to numbers falling from the sky while others shelter under purpose built structures to stop them being touched by them. Other figures attempt to catch the signals in nets, while elsewhere birds sing back to the falling signals with numbers of their own (see figure 4.6).

The radical and creative response produced by this participant made me want to develop the technique, using it to facilitate, to quote Gaver, "as many incompatible worlds as [my participants] wish to live in"[33] (p. 943). To approach the technique more skilfully I turned to Soomi Park and Raphael Kim, colleagues on my PhD programme who had completed the Design Interactions Masters programme at the RCA under Dunne and Raby.

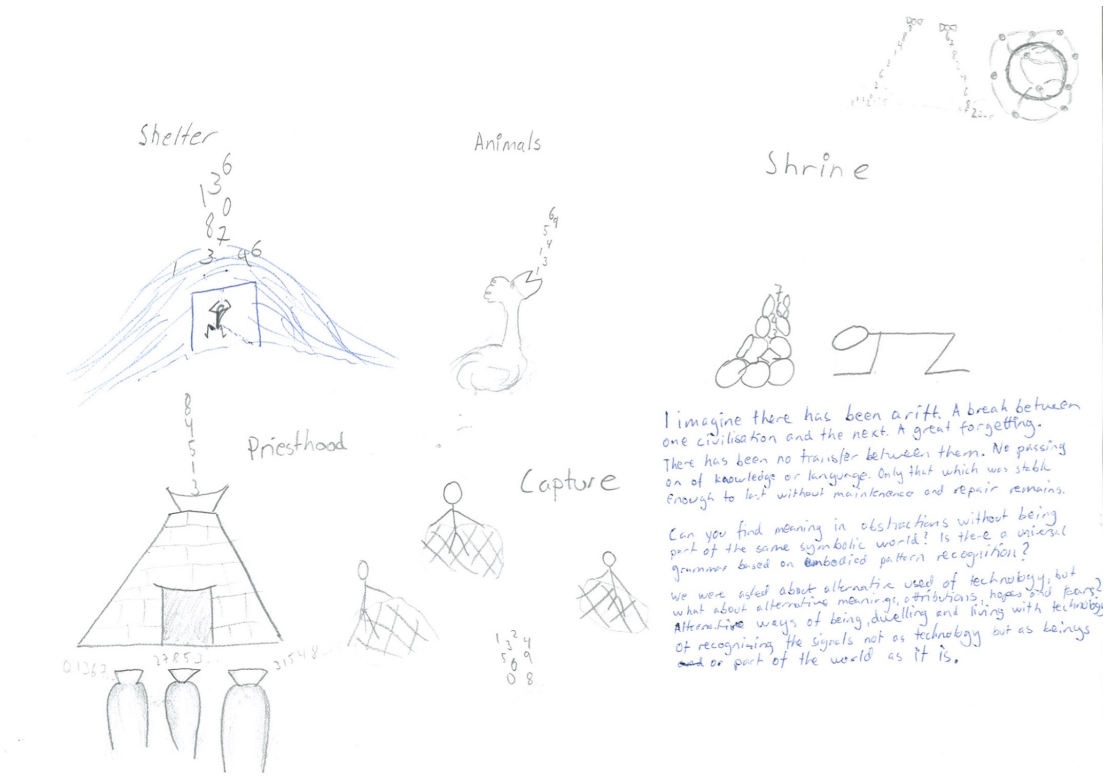

Figure 4.6: Participant drawing from Fengersfors, Sweden showing different ways in which GNSS signals may operate after a societal collapse.

4.2.5.2 Iteration

The first workshop took place in April 2017. I organised it with Soomi Park who has extensive experience running speculative design workshops. Within the workshop she provided logistical support and helped participants to develop their ideas in relation to the scenario prompt. The workshop was organised in association with The Culture Capital Exchange (TCCE), the research organisation I had worked with a year before to organise a walking experiment around the Barbican. It featured as part of a festival of workshops and presentations that TCCE were curating at Somerset House, London.

As before, working with a partner organisation raised its own advantages and compromises. The festival's programme was resistant to hosting a full day design workshop, we therefore condensed our workshop into a five-hour window. Again, TCCE allowed us access to their network of potential participants, but the uptake was lower than the

previous year, so we compensated by spreading a call for participation around undergraduate and masters design programmes in London. We received eight participants, two of whom were researchers, one artist and five design students.

The workshop began with a short mini-brief exercise which participants worked on individually. This was understood as a way to introduce them to the speculative design technique, rather than a way of probing the research topic. Each participant was given one of six different scenarios taken from the *Future Timeline* website [39]. They included potential future shifts in environment, biology and technology. After 40 minutes working on their concept they presented it to the group while Park and I gave encouraging feedback. After a break for lunch I presented a brief explanation of GNSS infrastructure, the same one I had given at the start of the walking experiments. Park gave a brief introduction to speculative design, highlighting some of the projects which had emerged from the RCA. This was intended to given participants inspiration for the kind of projects they could propose. After this we split the group into three teams and gave them 90 minutes to develop a design in response to the following brief:

2040: Global Navigation Satellite Systems Become Independent

> After 2030, rising global tensions around international trade and access to resources had begun to threaten scientific and infrastructural projects that required cross-border collaboration. GNSS systems were not immune to these problems, despite being extremely important to the global economy. After a series of political incidents, in 2035, China, Russia, America and the EU announced that they would encode the signals broadcast from their GNSS constellations. From that date forward GNSS locative services would not be available except to users who had the ability to decode the signals. The encoding took place in both the signals and the almanac of satellite positions, making it very difficult to crack. Decoding technology would only be available in the system's country of origin.

The brief was intended to draw attention to infrastructural aspects of GNSS systems which are more obscure; in particular, the territorial ground footprint of the infrastructures and their historical development in concert with national militaries. On Park's advice, it was kept extremely open, with the focus on creating a possible world rather than using the brief to preface too many of the relations within that world.

The outcomes from this brief were, however, also perhaps too open. Although we received three interesting projects, none of them wrestled with the material agency of GNSS, rather offering alternative user-centered practices grounded in GNSS in its present form. The projects are discussed in more detail in the findings chapter.

Based on this experience I decided to understand the above workshop as a developmental exercise. In analysis I weigh the importance of collected research data towards the subsequent workshops. These subsequent workshops featured a revised scenario that was less open and more focussed on the material agency of infrastructure. The scenario is as follows:

2050 Satellite Systems Become Self-Directing

> After a series of technical advances and budget cuts on earth, in 2040 it is decided to remove ground support from the world's GNSS systems. Technical advances in machine learning mean that the system can maintain and correct itself to the standards required to support existing uses. The corrective model has been trained on existing use data (in terms of physical environment - terrestrial and extra-terrestrial, time, terrestrial navigation, military support). After 10 years, the system has continued to evolve and begins to identify, decide on, and work towards its own goals, both on the earth and in space.

The workshops which contained this brief were much shorter. This was a practical decision following difficulties in recruiting participants for an afternoon-long study. Working this time with Raphael Kim, another RCA alumni and experienced workshop

coordinator, we gave a short introduction to the technical operation of GNSS systems and to speculative design as a technique. We then divided participants into groups of 2 or 3 and gave them 45 minutes to an hour to work on their design. As before they were asked to create an artefact through which to communicate their concept. During this design session Kim and I supported the groups as before, allowing their own ideas to lead the process. The session concluded with the group presentations and a reflective discussion. The presentation and subsequent discussion form the data used in the analysis. We ran two workshops with this brief and structure. The first was aimed at participants with an engineering background and took place at Queen Mary University of London. The second took place at Future Cities Catapult, a design and innovation hub in London staffed by people with a strong design background.

4.2.6 Limitations

Throughout the development of the design workshop, there were some difficulties in engineering an ontological shift away from the human user. The focus on this figure as the driver of sociotechnical practices remained strongly present during the developmental workshop. This lead me to engineer a change in the brief given to subsequent participants. While this shift did experience some success, the dramatic change in brief means it is difficult to reconcile the two sets of data. I have taken this into account in the findings and discussion chapter by weighing my analysis towards the later workshops. The work emerging from the first brief is understood as primarily developmental, and only described in brief in the findings chapter. It does, however, feature in the discussion chapter as a point of comparison.

Between this shift and the change in participants across workshops, the data collected here is somewhat fractured and fragmented. This is, in part, a consequence of the openness of this method in comparison to the walking method. While this is a limitation in that it means the data is harder to grasp and compare, it also speaks to the role of this method as generative and world-building, producing slippery and half-formed realities.

These limitations are taken into consideration through the analysis process and described in the findings and discussion chapters.

4.3 Conclusion

In this chapter I have described the development of my two poetic methods. Both are experimental in the sense that they work to make theoretical considerations the subject of empirical research using new techniques. In the first method, I used staging influenced by artistic practice to create a form of infrastructural inversion [1]. In this method, the artistic credentials of the method are worn proudly and form a significant part of the staging.

The second poetic method draws on speculative design [34], but offers it in a workshop format influenced by Matt Ratto's critical making [30]. This application emphasises the avant-garde and poetic tradition of speculative design as a way of critiquing established ontologies and encouraging the generation of new ones. In this way, it is an experimental technique, intended to generate knowledge by probing the edges of what is conceivable, creating metaphors and using them to access the ontological texture of GNSS infrastructure.

Both techniques went through several rounds of iteration in order to make them able to effectively address the research questions. This chapter described these iterations and the limitations which remained.

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Chapter 5

Findings

In this chapter I detail the findings of my two poetic methods. The first of these is the walking method using the *GPS Test* app. This method works to invert GNSS infrastructure, unpick its blackboxing, and thereby challenge established practices. The second poetic method is a series of short form speculative design workshops. These act to deepen a critique of the relationship between user and infrastructure by creating a future scenario that emphasises a shift in agency. In the future scenario, the organisation of the GNSS network has changed in a way that draws attention to their ability to act. Specifically, the scenario describes a world where, through unsupervised machine learning, GNSS infrastructures have become self-aware to the point that they decide their own interests and actions. Participants were asked to respond to this scenario by authoring interactions, artefacts and scenarios of their own that fit into this larger world. In both cases metaphor is important in the data as a means to point towards the textures of the infrastructures through their ability to act and, in turn, influence other actors.

In both cases, I describe the findings of the workshops, initially through description and then through situational analyses wherein the themes I glean from workshop data are combined with acknowledgements of the influence of research staging and agency of material actors. In the walking workshops, examples of material actors include the built

environment, or media narratives around privacy and locative gaming. In the speculative design workshops, examples would include the craft materials on offer or contemporary media narratives around artificial intelligence. These situational analyses are presented as narrative arcs detailing the research alongside its attendant contexts. I can then ask these narratives questions related to the success of the methods in addressing my research questions. The evaluation of the methods' success is covered primarily in the discussion chapter.

5.1 Summary

In both sets of workshops, I have worked to build an overview of the data that emerged, organised into themes and conscious of the research staging that influenced it. In the walking workshops I describe a shift in data themes from alienation from existing practices, through a revelatory experience in which buildings, satellites and human bodies exist within a wider ecosystem of signals. Within that ecosystem there are a series of overlapping dynamics which, thus re-framed, allow participants to re-consider the power relations at play in their existing practices and posit new ones based on different relationships with satellites. As described earlier in this thesis, the power of metaphor and poetics becomes a key node through which present understandings can be elucidated, questioned and re-thought, particularly concerning the centrality of the user in forging meaning and practice.

My analysis of the design workshops focuses on the modes of description which emerge to engage with the proposed future scenario. Participants use a series of "conceptual bridges" [1] to engage with the idea of a self-aware GNSS infrastructure. These are: the earth as a site of shared interest between humans and satellites; mapping as a practice that can facilitate power relations; and animal metaphors used to conceptualise non-human concerns. Through these tropes, several themes for infrastructural motivations emerge: control over human populations and resistance; satellites as a benign power or

guardian angel; GNSS as a tool which continues to serve human goals; and satellites which exhibit behaviour learned from human practices. These themes represent ways in which participants conceptualised the shifting boundaries between user and infrastructure offered by the future scenario. The types of metaphor used by participants are aggregated and organised into themes. These themes provide insight into the possibility of more-than-human networks, how they are conceptualised and how they can be understood to act.

5.2 Walking Method

In this section I describe the findings from the walking workshops. I divide the description of these workshops into two parts. In the first section I describe the findings from my first two workshops, held in the Barbican. I used these as open-ended experiments intended to identify themes in the way participants could rethink GNSS through the method. From these experiments, I established two major themes which I chose to explore in more detail: privacy and surveillance, and the impact of architecture on the functionality of GNSS. To concentrate on these themes, I went on to host a workshop focusing on each one. The workshops took the same form, but I mentioned the theme as I introduced participants to the task and tried to steer the discussion in this direction. These more focussed workshops are described individually.

In the second half of this section, I detail the situational analysis which I performed on the emergent data. While I took the drawings, writings and discussions from all the walking workshops together, in the analysis I incorporated the interventions I had made in focusing the later workshops. While the conditions across workshops were, therefore, iterative rather than completely consistent, I allow for this shift in my analysis.

5.2.1 The First Two Workshops

In this subsection I describe the themes which emerged from the first two experiments. These were conducted in April and June 2016 in association with TCCE and Antiuniversity Now respectively. The experiments involved a brief introduction, half an hour of free exploration around the Barbican Estate using *GPS Test* to see how the buildings produced moments of breakdown for GNSS infrastructure, around twenty minutes of individual writing and drawing, then, finally, a group discussion. As described in the previous chapter, the data presented here comes primarily from the discussion, with the drawing and writing used for support and illustration. These two experiments, taken together, involved 15 participants, the majority of whom identified as artists or researchers. In coding this data I was also guided by my experiences in the preliminary studies in Madeira and Sweden, although, because of the different form these early studies took, the responses of those participants are not included in this data set.

5.2.1.1 Surveillance and Privacy

In these workshops, feelings of surveillance were mentioned 13 times by 8 of the 15 participants. These were most frequently understood as having negative associations. In the words of one participant:

"Clocking 11 and sometimes 12 satellites made me feel watched, a feeling compounded with the oppressive concrete which made me feel a little small and quite claustrophobic."

The satellites were frequently understood to be the ones watching, even though, as technical objects, they are passive, sending out information which the GNSS sensor in the devices uses to aggregate position. The "watching" takes place further up the data chain in the form of location tracking, the satellites never receive location information. Nevertheless, they acted as a focal point for concerns around surveillance. While this interpretation of the system is certainly naive, as a metaphor I believe it still has value.

Responses such as this can identify overarching concerns with sociotechnical practices and emotional responses to the way that infrastructure is understood to act.

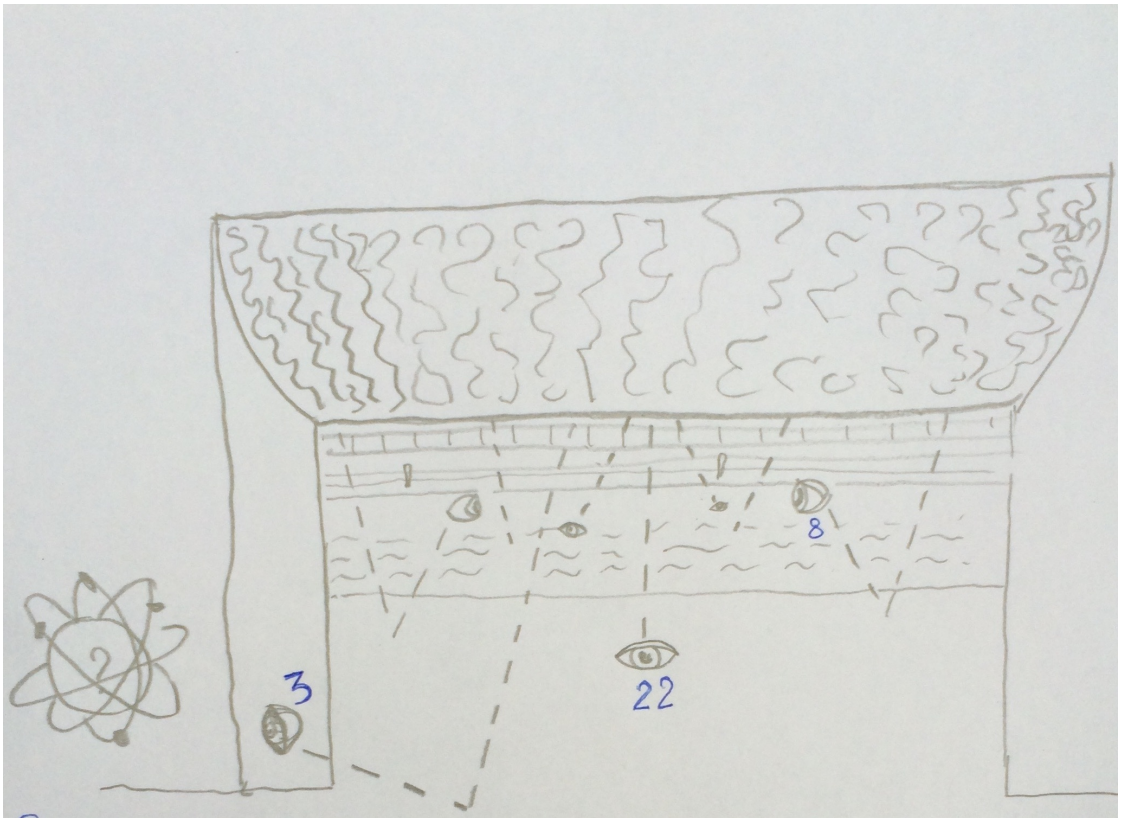

Figure 5.1: Detail from a participant drawing showing eyes descending from the sky, identified using GPS satellites' PRN numbers.

Indeed, other participants posited the watching satellites as part of a wider surveillance infrastructure, albeit, one that is monolithic. One participant, noting the points at which the device was not able to establish a location fix, wrote that "the all seeing eye has blind spots". This same participant described the satellites as an "imperial grid", suggesting that he recognised the satellites as one part of a wider infrastructure able to track location. For several participants, finding a point with low satellite coverage was understood as "hiding". One participant said they would like to have a map of where they could experience low coverage and thereby "escape" from the satellites. For another, the experience of participating in the experiment was quite visceral, linking back into their everyday practices:

> "I had this slight paranoia that I couldn't escape and in fact I do keep my location switched off most of the time because I don't like the idea of satellites knowing where I am, but in an abstract way, but this brings it home to me that they really do know where I am and they're really up there".

The idea the experiment "brought it home" to the participant that "they're really up there" is significant in terms of the successful framing of the experiment and will be explored in more detail later, it is also worth noting a strong resonance with increased awareness of being tracked.

Much like the participant who understood GNSS satellites as part of an "imperial grid", another abstracted the presence of the satellites to a wider political ecosystem. He described it as:

> "Kind of scary in a way. It makes you think about possibilities for control and also writers like Orwell and how it can be used for good or bad. Still, we mostly rely on this technology on a daily basis"

For this participant the technology has "possibilities for control" which are "kind of scary". However, he also recognises that our relationship with the technology is more complex. It "can be used for good or bad" and is something we rely on "on a daily basis".

From these first two experiments therefore, surveillance and privacy (in the sense of not being observed) emerged as a strong theme. In reviewing the data, I did get a sense that many people had a knee jerk negative reaction to what is a complex set of interactions. The final participant mentioned here understood the technology as something we use every day and that has potential to manifest in different ways. The theme, therefore, struck me as one which could benefit from deeper attention. I felt that a more developed investigation into the texture of the technology could interrogate this idea of the infrastructure as vast, monolithic and sinister.

5.2.1.2 Architecture

Another strong theme in these first two workshops was architecture and its relationship to GNSS signals and infrastructure. The theme manifested in two key ways. Firstly, participants described points in the estate at which they experienced interesting interactions with satellite signals. Secondly, participants took on the theme of architecture in a more conceptual sense, including how signals move through buildings, and the potential for rethinking the built environment in these terms. The conceptual theme which emerged here seemed very promising for my research questions, because it dealt with interactions between different material agencies (the agency of GNSS satellites and electromagnetic signals and the agency of the built environment) in which the user was less privileged.

For several participants, the prompt which made them think about the relationship between signals and the built environment was discovering that they could receive GNSS signals while inside if they were next to a window. One participant put it this way:

> "Can I communicate with satellites indoors? Concrete spiral staircase with glass windows. Stand still. This is the first victory. I have made contact from inside the concrete labyrinth. Windows are the key."

A similar realisation led another participant to wonder about the potential for satellites to map buildings according to their penetrability, asking: "could you do something whereby if you had a really accurate one of these [holds up tablet] could you work out what kind of building you were in? Almost map it using the signals coming down and coming through". This proposal presented a different way of orienting oneself in a building, leveraging the presence of signals as a kind of inverted sonar to build a map of the points where signals could penetrate.

Other participants understood the idea of signal penetration in terms of the design of the wider cityscape:

> "Thinking about architecture and buildings. Obviously at the time this

> was built, it was not built with signals in mind, and I was wondering to what extent [buildings] are built now with the realisation that actually these signals are sort of critical to many peoples' lives, and to what extent are dead zones avoided or at least for these spaces, does GPS and telephone signal matter?"

The discussion took place in the courtyard in the centre of the Barbican, with some of the office buildings which form part of the City of London visible around. Later in the discussion, another participant used the surroundings as a prop to make a similar point:

> "I mean if you look over there, that's how cities get built now, hyper densification. And we rely on signals more and more and its completely incongruent. Everyone has a smartphone pretty much and, if that's how we build cities - super-dense - then that's completely ill-suited to how we actually use this technology."

This quote points to the generative potential of this exercise, uncovering new ways of not only thinking about the world, but perhaps re-thinking its design, according to previously hidden sets of relations.

Participants also used the presence of signals, as evidenced by their relationship with architecture, to think in wider terms about the different types of signal in the air. One participant noticed that they had 4G signal in one of the car parks, but not GNSS reception. He "found it really interesting to wonder what part of that underground building made it ok for the data signal, but not for the GPS signal". Expanding from this architectural evidencing of different types of signals, some participants were moved to consider the presence of a wider signal ecosystem. The same participant who wondered about the relationship between 4G and GPS titled their drawing "walking into signals" (see Figure 5.2). Another wrote:

> "There are so many human made interferences in the air, if we don't hear it with ears we can probably feel it in some other way. Like this age in time is just overpopulated with signals. We are usually not even aware about it,

but they are there all the time influencing our lives in some way."

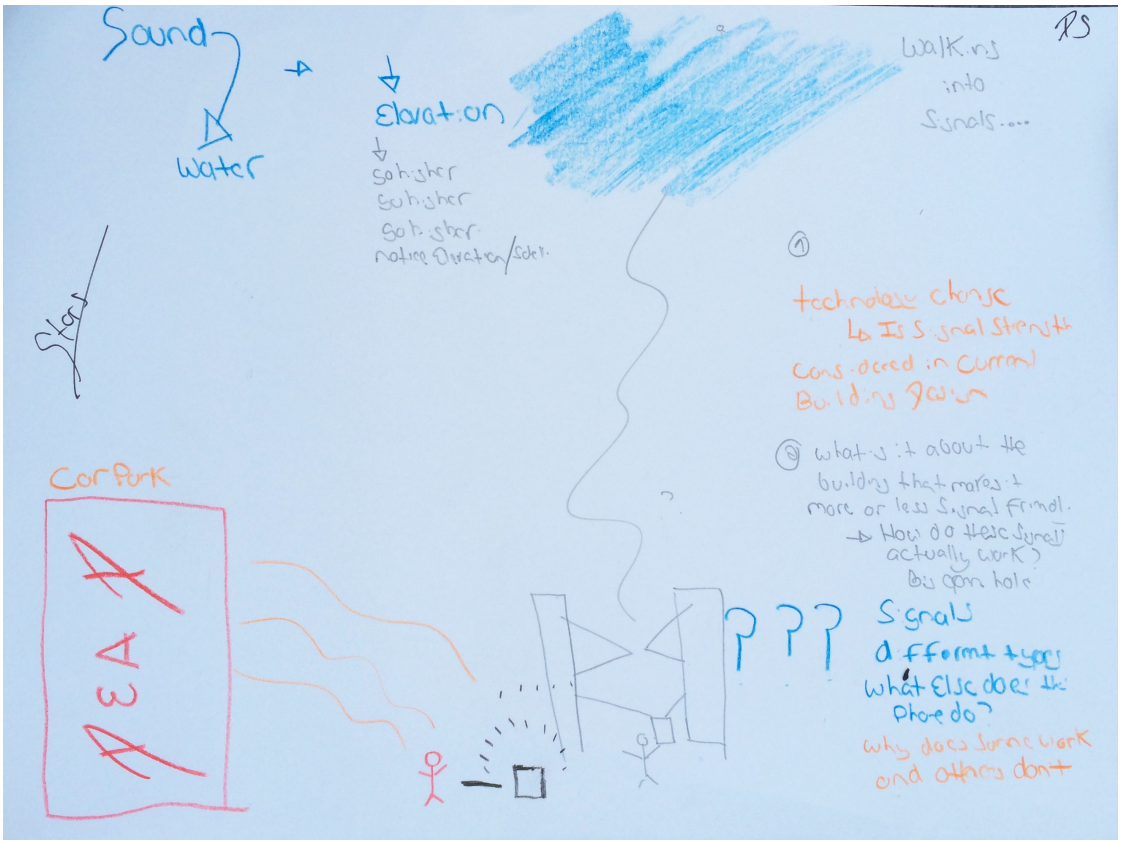

Figure 5.2: Participant drawing showing a signals coming down from the sky and reflecting off buildings. The drawing is titled "Walking into Signals".

The idea of being bodily affected by an 'overpopulation' of signals felt "in some other way" was mentioned by another participant, describing:

> "this whole nested scale of different kinds of signal which are penetrating your body, your phone, the building around you, and you're also part of that structure in a way, you know, you're accepting, receiving, deflecting all this stuff as well."

For this participant the presence of the body within a signal ecosystem is equated with the presence of buildings. Just as buildings accept, reflect and deflect signals, so does the body.

The theme of architecture (understood in an expanded, conceptual way that includes signal architectures), therefore emerged strongly in the two initial workshops. It both provided a prompt to consider different possible relations with GNSS infrastructure and acted as way of evidencing the existence of an electromagnetic realm of different signals. In this way, it opened up a rich discussion which spoke to the material texture of the infrastructure and a foregrounding of more-than-human networks. Encouraged by the way this theme was grasped by the participants, I thought it could also benefit from further exploration.

5.2.1.3 Interface

At this stage I also noted the influence of *GPS Test*'s interface. This point is highly relevant to an analysis of research staging and emerges in two ways. Firstly, the visual aspects of the app repeatedly worked their way into participant drawings. For example, one participant described *GPS Test*'s bar chart as "a city skyline" (see figure 5.3). A far more common response to the app's interface was to incorporate numbers into drawn responses. GPS Test's interface prominently features numbers to mark how many satellites are in view and in use and to differentiate each satellite using a pseudorandom number (PRN). Numbers also feature strongly on the bar chart view, with the PRN again prominently displayed along with the chart's legends. Other participant drawings combined text with either blocks or meandering lines of numbers (see Figures 5.4 and 5.5). Others referred to them in their text or discussion as a way of understanding the presence of satellites.

The second way in which the interface of GPS Test made its presence known was through complaints that it either displayed too much information or was confusing. For one participant this was connected to their own sense of efficacy in navigation:

> "Seeing the dial with the compass points. That's not something I'm usually good at. When someone says go north, I have no idea what they're

Figure 5.3: Participant drawing showing *GPS Test*'s bar chart re-imagined as a city skyline.

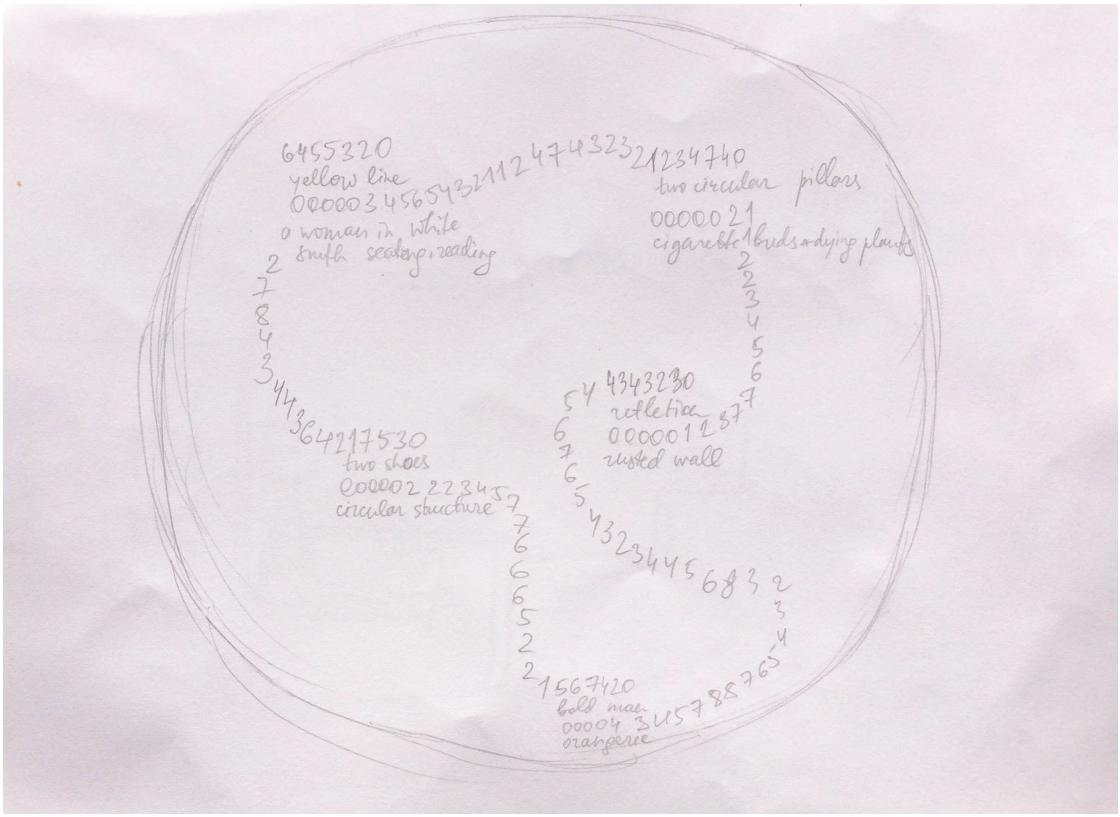

Figure 5.4: Participant drawing showing meandering lines of numbers, emphasising the importance of numbers in the interface.

saying. I'm not good at that."

Two other participants pointed to the features of the app which were not explained in the experiment introduction. One describing them as a "flood of information", while another acknowledged "a lot of information that we didn't reference. I don't know what

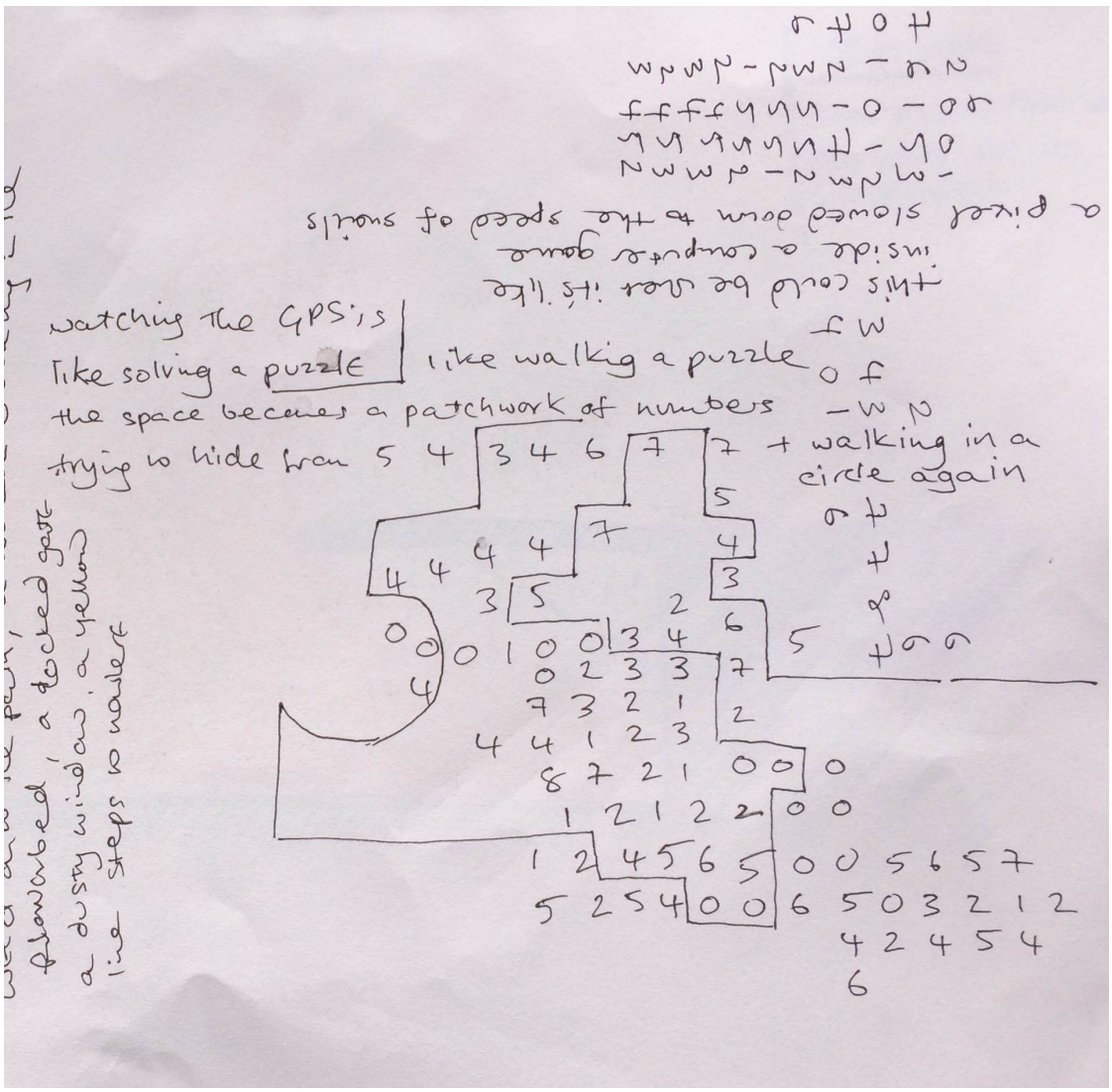

Figure 5.5: Participant drawing showing blocks of numbers, again emphasising the influence of numbers in forming visual meaning from the experiment.

a lot of it meant." Indeed, the possibility of reimagining what kind of interface could display the relevant information, came up several times with participants in both groups suggesting a map. In the words of one participant:

> "It made me want to turn it into a map actually you could imagine it when you show the contours. So, a contour map of where you could escape, so you could look at it and think if I want to get out of range I could go there."

A participant in the other group took it upon himself to begin making such a map during the walking exercise (see figure 5.6).

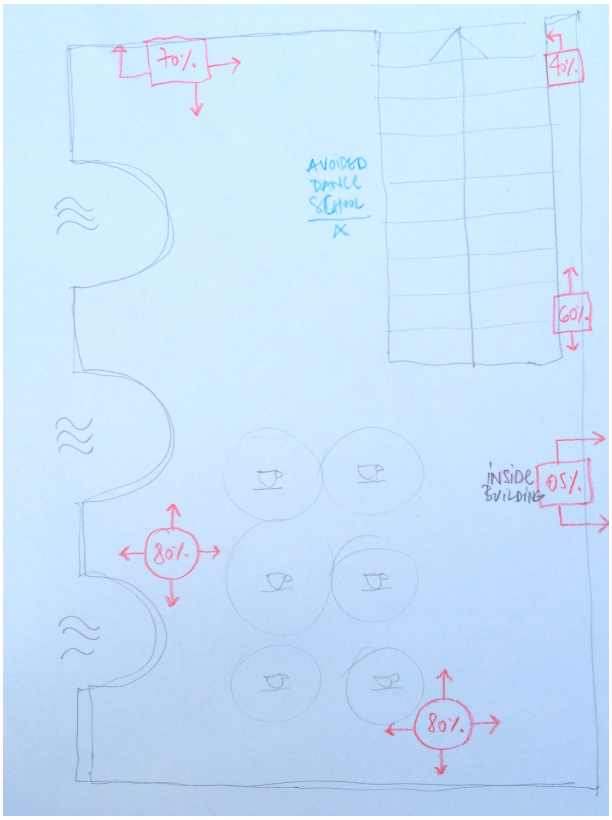

Figure 5.6: Participant drawing showing a map they made of relative GNSS coverage.

The prominence of the mapping idea suggests several things. One could argue that traditional ways of relating to space using GNSS remain influential, with mapping, orientation and navigation featuring prominently in participants' thoughts. We might also note that the map suggestion demonstrates a move to filter down the most relevant information from the app, again tying into the surveillance and privacy theme by pointing to coverage and the possibility of escape.

5.2.1.4 Review

Based on these experiences, at this half-way point, I decided to repeat these workshops, but concentrating on the two strongest and most promising themes to advance my re-

search. The theme of surveillance and privacy was something which was powerful, but only seemed to have been dealt with superficially. Making it the focus of a repeat workshop would be a way to see if this method could successfully focus in on specific areas of concern in more detailed and nuanced ways. The other strong theme of architecture and signals seemed to elicit powerful responses which were also conceptually creative. This theme also mapped well onto my research questions by addressing more ontological concerns, especially in relation to shifting understandings around more-than-human networks. The electromagnetic realm provided a way to discuss intra-actions [2] across material and non-human elements; satellites, signals and reflective buildings.

I therefore decided, in my next step, to repeat the workshops, keeping broadly the same format, but asking the participants to concentrate on these themes. This iteration met with mixed success and is discussed in the following sections.

5.2.2 Surveillance-Themed Workshop

In July 2016 I organised another experiment in the Barbican. The workshop format was the same as before, but participants were encouraged to concentrate on themes of surveillance and privacy. This workshop was self-organised, and, as a result, I received fewer participants. Of the four who attended, one identified as an artist, two as researchers and one as a journalist. Three of them were friends known to me before the workshop.

Perhaps because of the lower numbers and my existing relationships with some participants, the group remained well focused on the topic, producing a lively discussion. They did, however, also cover other themes. Some of these were shared with previous workshops and therefore expected. Others emerged later during situational analysis. In this section I will concentrate on the discussion that emerged around the focus topic of surveillance and privacy.

At the start of the discussion two of the participants said that they keep their location setting disabled, with one saying he had not turned his on since “2009 or 2010”. He said

he did this as he did not want to "leak information about myself". When pressed, he described a feeling of mistrust towards those people who handle location-derived information:

> "I don't feel like I do anything where I explicitly feel like I would be surveilled for that thing, that activity, but I know that information is used beyond its immediate descriptive capabilities. So that exercise of state or corporate power is not just in the hands of people who understand the specific limitation of the technology, but also people who have had it explained to them third hand. Because most of this stuff is relatively new, there aren't a lot of people who can distinguish between the two, so I'd rather not leave a trail of breadcrumbs everywhere."

Generally, participants expressed some discomfort with the idea that their location could be tracked. One said that, in turning off the location option on their device: "I don't really think I've interrogated why I do it, just the knowledge that reducing whatever trail you leave behind you feels like quite a good thing", while one described the use of location services as:

> "an uncomfortable trade off between what information you're willing to give a corporate company or the state or whatever and the service that you get in return. And that line changes for me quite a lot. I'm quite, maybe, uncomfortable about the trade off, but I'm willing to use Googlemaps because it's really useful, even though I kind of know that, that even though I'm using a service, the service is using me just as, probably more than, its used by me. When you actually see visually how many of them [satellites] there are, I started thinking a lot more about the information flow the other way."

This participant was aware of the value her use of locative services was creating for others, but that knowledge existed in the background and was not engaged with at every moment of use. Another participant made a similar observation about his use of other

services which use a data trail:

> "When you pay for things on contactless you're leaving a trail as well so it's that weird thing where you'll focus on one thing and not on the other, but it definitely makes me think quite a lot about the kind of dependencies which are built into the way we live now compared to even like 10 years ago."

These reflections speak to the way in which GNSS supports practices which begin to form other kinds of standards and infrastructures, of a kind which are submerged and seamless [3].

The same participant works as a researcher. In his work he uses GNSS technology to track, and thereby predict, bird migration patterns. He drew parallels between the work he does in tracking birds and the idea that he, himself could be tracked:

> "The insight into the large scale movement of non-human organisms around the planet has been pretty amazing. but again a lot of the technology that gets developed in the process of understanding that kind of behaviour also has potential implications for surveillance. So it's really interesting working on those kind of projects where what you're actually doing is using my machine learning statistical methods to try and predict behaviours out of these tracks. Someone could take these kind of methods and use them to predict what a person is doing just as easily."

Again, the idea of a trade-off is present here, GNSS technology can bring great gains to research, but can offer threats to privacy. Such a double-bind raises questions about the positioning of the researcher and the power-interactions implicit therein.

The trade-off concept also emerged in story which a participant's friend who works in international development had told relating to the recent mass-movement of refugees across Europe:

> "She said she was talking to somebody who was travelling from Syria and

> I think was somewhere in the kind of Balkan region and she was like, do you ever get lost and he was like, no I've got GPS. And it was just funny you were talking about tracking human migration because it's an interesting trade off, right? To what degree are people able to be tracked during that period of movement versus to what degree that actually enables them to orient themselves."

In these ways, the discussion moved on from GNSS infrastructures alone, beginning to also incorporate the kinds of practices which they support. Inspired by seeing "how many of them [satellites] there are", participants began to unpick what the presence of GNSS infrastructure meant for both their own practices, for other groups such as refugees and even for non-human groups such as migratory birds. I judged that this discussion had been quite successful in deepening the discussion around surveillance and privacy, using the visibility of satellite infrastructure to expose and unravel other concerns which frequently fade into the background. This success was tempered by an awareness that, along with iteration, comes a danger of overfitting a research method to a given research question. I was also aware that surveillance and privacy had featured strongly as a theme both in my preliminary experiments and outside the research process in casual conversations about my research. It therefore seemed like the easiest, most present theme to access. I wondered if a focus on architecture and signals would produce similar results.

5.2.3 Architecture-Themed Workshop

The second focused experiment concentrated on the theme of architecture and took place in Manchester in August 2016. As previously discussed, it should be acknowledged that this workshop took place in a different location and a slightly different form. Although the artist and researcher demographic was present, the participants were from a broader set of backgrounds than in the experiments in London. There was also a change in the flow of the workshop, influenced by the nature of the site: Rather than exploring individually, the group moved (more or less) together between set points. This decision

was made because, unlike the Barbican walks, the experiment did not take place in a contained site. Also, the route was subject to change and diversion according to the suggestions of participants with more detailed local knowledge. The focus on architecture led me to encourage the group to explore different forms and types of building. Therefore, we moved through an area of 21st century regeneration, Victorian alleys (see figure 5.9), a large Victorian wool exchange (see figure 5.8), and a 20th century shopping centre (see figure 5.7). We also stopped at buildings and spaces of different scale and orientation, with different degrees of visibility to the sky. I intended that the comparison between these different forms of architecture would, following on from the previous workshops, encourage participants to think about how different buildings were developed for different types of access, movement and visibility, as technical infrastructures and signal movements became more relevant over time. I also hoped these prompts would be conceptually inspiring in a similar way to what I had seen in the initial workshops.

In practice, the theme of architecture inspired limited attention from the participants. One experienced the difference in architecture as unsurprising, stating:

> "I mean the building we went into with the glass roof - you'd expect to see a signal in there and sure enough we did - usually it's quite predictable."

In response to this point, another participant was more engaged, stating:

> "I think it's quite interesting that's it's the more modern buildings that signals can penetrate and whether that's something to do with just modern building materials and the way buildings have evolved in the past few years, or the fact the signal penetration is just going to become a factor when people are designing buildings in the future and that's going to change the look of them, I don't know."

Other participants were interested in the kind of sense which satellites might make

Figure 5.7: The glass roof in the Arndale Centre, Manchester ensuring a smooth flow of GNSS signals.

of buildings through the building-signal interaction. Reflecting on the walk through the recently redeveloped area, one proposed:

> "I found it interesting being around the high-sided buildings and near the sharp edges because when you're in the middle of a walkway, the signal seemed to be really clear. There was a parameter in there that showed the accuracy [signal to noise ratio] and you may have thought that the nearer you got to a building, the less accurate it would be. But I found something that was more consistent than that is as you got to within four feet, it suddenly went completely haywire, but when you got clearer from the building, it suddenly became clear again when you sort of push against. Then just at

Figure 5.8: The glass roof of the Royal Exchange, Manchester.

> the last bit where you got to the hard surface, it suddenly became clear again. I found that quite consistent. So that's why I started to draw around that because you've got this area of confusion that's four feet around all the buildings. It's kind of like an image if you like, if you can imagine the satellites being able to look at the buildings, that's what it would looks like. There's halos round everything."

This rich description proposes a form of sensing generated by electromagnetic signal (see also 5.10). It is a similar idea to the possibility of satellites mapping buildings through signal penetration proposed in an earlier workshop, but here the participant acknowledges the way in which signal reflections could change the nature of the image produced. Another participant pointed to similar ideas of satellites seeing or reading the city, in their writing they proposed the idea of the "city as braille". This phrasing suggests the blindness of the satellites and the idea of signals as something tactile reaching down from the sky and feeling their way across buildings. While most other participants had used visual metaphors to invoke satellites "seeing" the ground or themselves being "watched" from above, the idea of the city as braille suggests a different mode of sensing,

Figure 5.9: Boardman's Entry, Manchester. A narrow alley offering limited views of the sky.

more embedded in texture, touch and materiality.

These participant statements were rich and encouraging, feeding back into my questions of how GNSS could be understood if we push the user back from the foreground. However, these were the only comments which directly addressed the architecture theme. Despite several early attempts to direct the discussion, the rest of the time was spent discussing themes of surveillance, the benefits and dangers of hiding from "the man" and *Pokemon Go*, a locative game that was experiencing a lot of press coverage around the time of the workshop.

I was initially discouraged by how this workshop went and reflected that the more diverse group and different site and staging may well have had an effect in preventing a

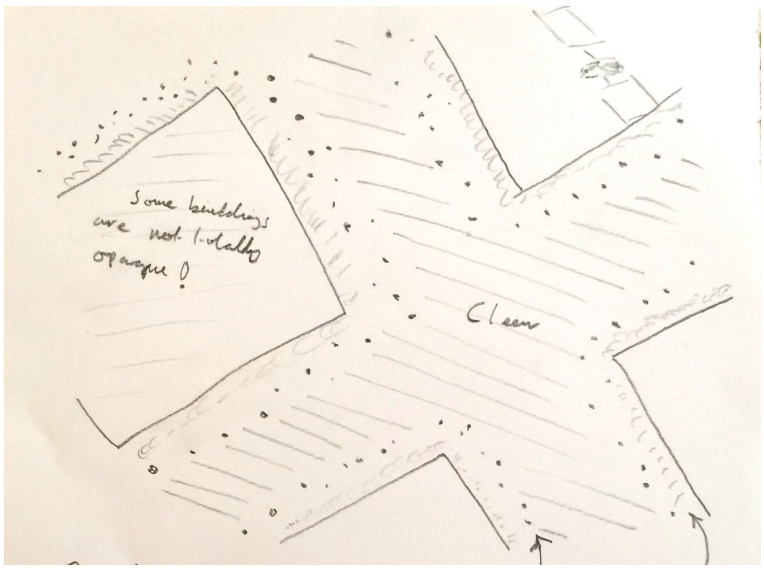

Figure 5.10: Participant drawing showing a reflective "area of confusion" around each building.

rich discussion around my proposed theme. I would like to acknowledge the influence of these changes, as well as the media landscape at that moment, but it is also important to recognise that, as a researcher, I was responsible for directing the workshop in a certain direction. By trying to push the work down a specific path, in many ways I was setting myself up for a fall. At the end of this workshop I had more data, but wasn't quite sure if or how it fitted into my original plan of moving from general towards more focussed workshops. I felt I had reached saturation. I therefore decided to take a step back and reconsider everything I had collected using situational analysis.

5.2.4 Situational Analysis: Walking Workshops

Situational analysis is a technique proposed by Clarke [4, 5], emerging from grounded theory principles, but also incorporating situational influences; the presence of different objects and the intentions of the researcher. By allowing me to incorporate researcher intentions, it resonated strongly with the iterative research path I had taken through these workshops. It also resonated with the theoretical influences brought by Karen Barad's work which understands agency and objecthood as emergent across an assem-

blage through intra-action between human and non-human elements [2]. Situational analysis is described in more detail in the previous, methods chapter. In the following section I will briefly describe how I worked from a messy map towards a cleaner one. The second half of this section describes the themes which I understood to emerge when I posed my research questions to this situational map.

At first I listed all the other elements which had influenced the research process and code ideas which had been abandoned along the way, giving them the same weight as the codes which I had spent the past few months developing. To give a sense of the process, I offer a list of these:

Architecture, Invisibility, Alternative interfaces, Hide and seek, Background of participants, Indoors / outdoors, Smartphone, Surveillance, Visual interface, Other signals, Media context, Partner organisations, Looking for direction, Mapping, Companionship with satellites, Inversion (watching satellites), Scale, Reliability, Satellites as objects, Getting lost, Latency, State actors, GNSS signals, Satellites as watchers, City as braille, Numbers, Familiar use contexts, Satellite trails, Probing, Military actors, Corporate actors

From here I began to map which were connected. Through a series of iterated maps I began to organise them into groups, cutting, adding and combining a few along the way. I emerged with the following list of groups:

Spatial aspects (from the site)

User affects (feelings and metaphors found in the data)

Non-user actors (other material actors which exerted an influence on the experiment)

Researcher's Intentions (what I, as a researcher brought to the experiment with my concerns)

User practices (the emergent ways in which participants interacted with the experi-

ment)

Contextual elements (other contextual aspects in participants' experiences)

Other Emergent Concepts (other things in the data which seemed significant)

I then built a map linking each sub-element in these groups. Once this map had been iterated and felt fairly stable. I considered my research questions in relation to it. I asked what happens when attention is directed away from the user and back onto the infrastructure and drew the map detailed in figure 5.11. While my paper, working version was more complex, for ease of reading, in this presentation version, I've only included some more important links between sub-elements in each group. For example, the user affect of paranoia is connected to the contextual element of privacy concerns and the non-user actors of the US military and data-mining of location services. In another example, the user practice of inversion is linked to the researcher's intentions of creating critical discourse.

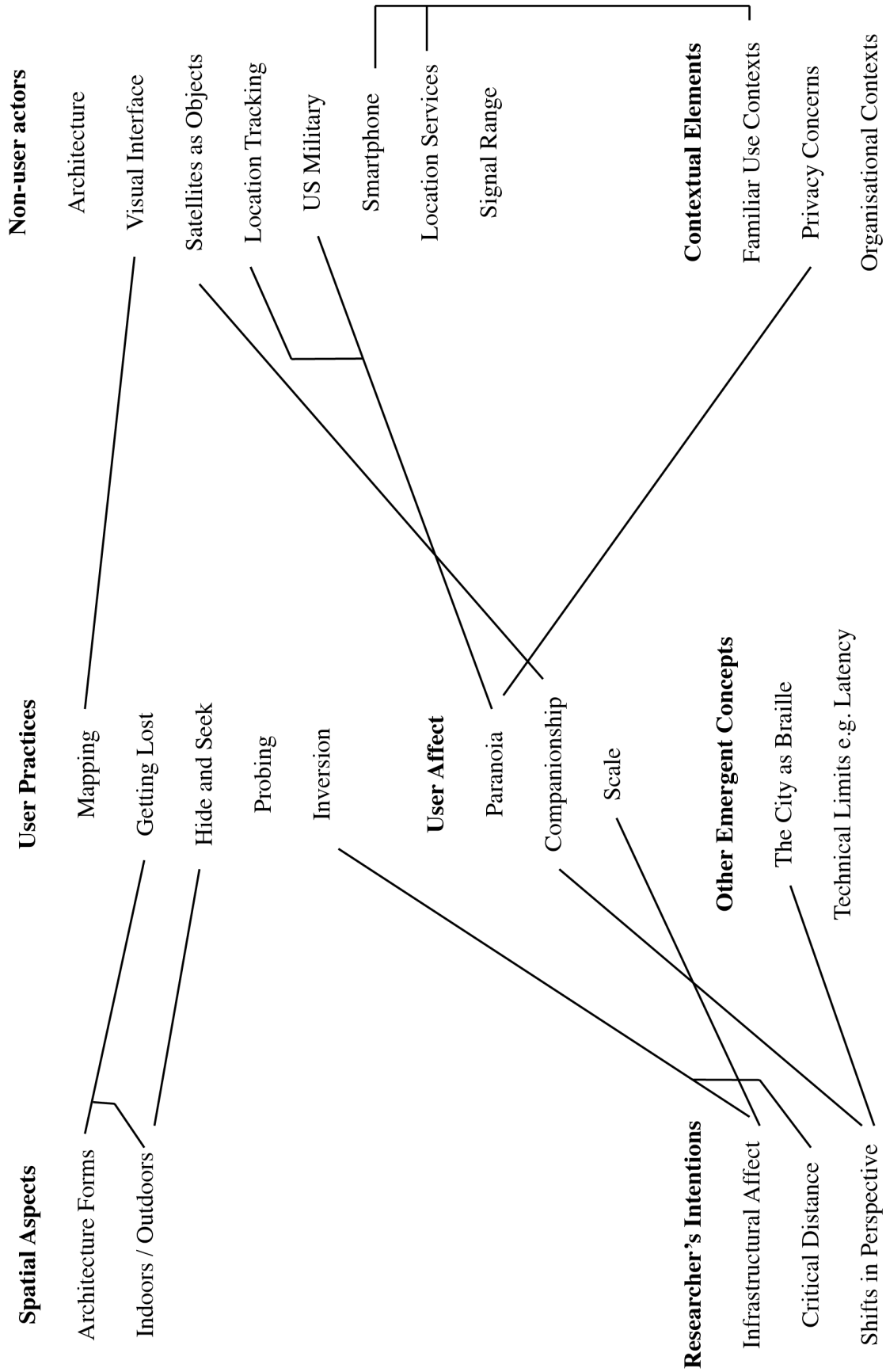

Figure 5.11: Situational analysis from the walking workshop data.

5.2.4.1 Initial questions

My first question for the data was whether I had succeeded in making GNSS infrastructure more visible. In three different workshops participants identified an "inversion" of the usual operation of the technology. The change was understood as a shift in what was being located by whom, so "you could see them [satellites] rather than being seen":

> "I'm used to me on Googlemaps being a little blue dot, so in a strange way I thought there's something quite subversive about the satellites being located by me. Locating the satellite rather than locating yourself was fun to play with."

The position of the satellites provided the point of contact with GNSS infrastructure. Other physical elements of GNSS infrastructure such as ground antennas and control stations remained concealed, as did the techniques and standards which fed into the design and testing of the satellites. These elements were embedded within the satellite, which was understood as a coherent and distinct object. This understanding was supported by the placement of satellites as individual dots on the visual interface.

Despite these caveats, the exercise did allow participants to think beyond conventional user experiences and, as we shall see, use satellites as prompts to reflect on their sociotechnical practices and consider the texture of the infrastructure. This manifested in several ways. In the following subsections, I describe participants' responses beginning with alienation, moving through awareness of an infrastructural context, to reflection on some of the textural dynamics at work within that awareness.

5.2.4.2 Alienation

A sense of removal from usual tasks was experienced by several participants. This was felt through a re-orientation, where "the whole sense of direction became a bit more abstract and didn't seem to include me in it", or, in broader terms, everything on the site became

"surreal". The participant who noted the "surreal" also stated that "this could be what it's like inside a computer game - a pixel slowed down to the speed of snails". This sense of disassociation was interpreted in terms of the scale of the infrastructure by another participant:

> "The experience of reminding myself of the relationship between device and satellite had the same impact as when I'm in a space where I can see the stars. I often forget that I'm on a planet, one of many in a much bigger space, and whenever I see the stars it has an impact. So, for me, it's a slightly humbling experience. This experience has just reminded me of this scope of things, the ecosystem that is my life, the universe and that came off very powerfully when I sat down and started to look up."

Here the scale of the infrastructure sparked a removal from everyday concerns and created reflection back on the profoundly large space and time of the universe. For him, stars acted as a point of comparison for the presence of satellites, indeed, the comparison also exists in the design nomenclature where an array of satellites is called a 'constellation'.

I would also note that, although the aspects specific to GNSS infrastructure (such as scale) certainly contributed to a sense of alienation, the staging of the exercise undoubtedly had an influence. One participant wrote that the exercise felt like a 'techno-derive', betraying knowledge of the work of the situationists [6]. He described how wandering without a task emphasised his sensory experience:

> "The thing was, not having to go from 'A' to 'B', it made me acutely aware of my body in relation to the temperature, humidity, sound. All of which could change with the pungent smells from the kitchen air extractors. The magnified distant booming of vehicles unloading, trolleys on prams bashing over textured flooring."

This enhanced sensory experience is similar to that which lead one participant to

report an experience felt "at the speed of snails" suggesting a different level and type of engagement with participant surroundings. Although it may be from a mix of causes, responses of alienation from usual practices were widespread, thereby laying the groundwork for a more nuanced engagement with infrastructure.

5.2.4.3 Environment

In taking their attention away from their usual practices, several participants were provoked to think about the presence of electromagnetic signals in their surroundings. This feature of the infrastructure was, again, partially driven by the experiment design and use of *GPS Test*. Through the app, the presence of satellites was revealed, but a secondary effect was the awareness of signal paths which allowed a given satellite to be designated 'in use'. The presence of GNSS signals made participants also consider how rich the air might be with Wi-Fi, cell phone and radio transmissions. Signals became a dominant theme in one of the discussions and appeared in two others. One participant "wonder[ed] what else was around", while another questioned the nature of those signals as a surrounding medium:

> "The question of how ethereal is this, it's like what are we actually moving through? What's the world that we're existing in and how much of it are we aware of?"

For both these participants, the revealed presence of infrastructure raised questions, both of what was there and how it affects them. Another participant made a stronger claim, positing a whole ecosystem, which they, themselves were part of:

> "So, you've got like universal background static all the way down to these super-precise signals and very short range signals which are probably coming from Wi-Fi routers in the building or peoples' phones and it's this whole nested scale of like different kinds of signal which are penetrating your body, your phone, the building around you, and you're also part of that structure

> in a way, you know, you're accepting, receiving, deflecting all this stuff as well."

This understanding of oneself as a reflective and receptive body within a structure of signals marks something different from initial experiences of alienation. The participant has proposed an alternate system in which the user's body, phone, Wi-Fi and long-range signals are understood as an overlapping and interacting web. It is not clear in what sense this participant would or would not understand this dynamic structure as an infrastructure in the terms proposed by Star and Ruhleder [7], but the possibility of finding oneself within a system of ambient, ongoing interactions speaks to Barad's view of causality in which users and infrastructures can be understood to emerge from collections of phenomena [8]. Such a re-orientation offers the possibility of re-thinking relations with GNSS infrastructure through awareness of different formative agencies. Within this shifted awareness, we can begin to think about how sociotechnical practices are reconsidered and infrastructural texture is understood.

5.2.4.4 Dynamics

If it is possible to imagine a wider system of interactions between body, device, a scale of signals and technical objects, we can then ask what dynamics exist within that system. Those dynamics, a means of understanding infrastructural texture, were surely experienced differently by each participant, but nevertheless some common themes emerged. At this point of the analysis I place, re-state and re-orient some of the codes and themes which I identified during the first pass at the data.

Every discussion exhibited a strong theme of play and experimentation. Participants chose to describe the activity variously as "hide and seek" or "like walking a puzzle". The process reminded another participant of "not stepping on the cracks when you're a kid". Within the app, when a location fix was possible, all the satellites in use would light up, when it was not, all the satellites would be greyed out. As a location fix provided strong

visual feedback to participants, it is unsurprising that they would focus on this action. What does require more explanation, however, is that many of them understood this as play. In some ways, this aspect suggests a more open interaction with the infrastructure, one distinct from typical task-based practices. However, as a game, hide and seek does come with some basic roles and structures around the visibility of the participants.

This act of hiding can be understood in part as testing or, in the words of one participant, "probing" the infrastructure, but it also resonates strongly with the theme of surveillance and privacy which was a constant throughout all the workshops. While it was noted in the workshops' technical introduction that the satellites themselves are merely emitting signals and they do not 'see' activity on the ground, the trope of spy satellites with observing eyes was persistent. The strength of this metaphor suggests that being watched and followed by the wider infrastructure (including location services further up the data chain) is an extremely powerful textural concern.

Even without a direct link from satellite to surveillance, participants were aware of the collection of personal data by corporate and state actors further up the data food chain. The asymmetry of power implied by an infrastructure on such a scale did not escape the notice of one participant who referred to the satellite constellation as "the imperial grid" and "the all-seeing eye". While another described it as "kind of scary", reflecting on "possibilities for control and writers like Orwell and how it can be used for good or bad". Another participant voiced more specific concerns, stating that: "While I don't feel like I do anything where I would be surveilled for that thing, I know that information is used beyond its descriptive capabilities." Furthermore; "state or corporate power is not just in the hands of people who understand the specific limitations of the technology, but also people who have had it explained to them third hand." This comment betrays a lack of confidence in both the limits of explanatory power of location data and the ability of data-handlers to recognise those limits.

Several other statements were made along these lines including one participant who described a privacy calculus she makes between giving up personal information and

having the convenience of a locative service like Googlemaps. For her, the experiment made her "think about it the other way", that "even though I'm using a service, the service is using me, probably more than it's used by me." The trigger for this reflection was "the visual nature of having something like that in the sky. It brings it home to you, that they're really up there." Here, GNSS infrastructure was as a stand in, an implicated composite part of a wider infrastructure concerned with tracking the movement of people and devices. When this infrastructure was revealed, she reflected on the way she forms her usual practices around personal information.

Although this participant experienced the presence of GNSS infrastructure in an unsettling way, others responded to the satellites differently. During the Manchester study, several participants noticed that, despite their best efforts to "hide" from satellite signals, one satellite was more persistent than the others. Number 26 (named from its Pseudorandom noise (PRN) code) was described as "the plucky satellite that was still holding on when all the others were vanishing" (see Figure 5.12). The persistence of this one satellite, while likely more the result of its position in the sky than any property specific to it, allowed the experience to "become personal", inspiring one participant to report:

> "I was almost I don't know, really surprised about how it felt inside, rather than this kind of scientific gadget, cos I'm not a particularly gadget-y person, and I found myself completely transfixed by it."

What is perhaps most noteworthy here is that a "personal" relationship with a satellite can become possible. This is, in part, a result of the power of the visual interface which depicts satellites as distinct, numbered moving dots on a chart. While, strictly speaking, the satellites act primarily in concert, with four signals needing to be received to establish a reliable location fix, the design of the app presents satellites as discreet objects. This reveals the interface's continuing ability to influence user responses.

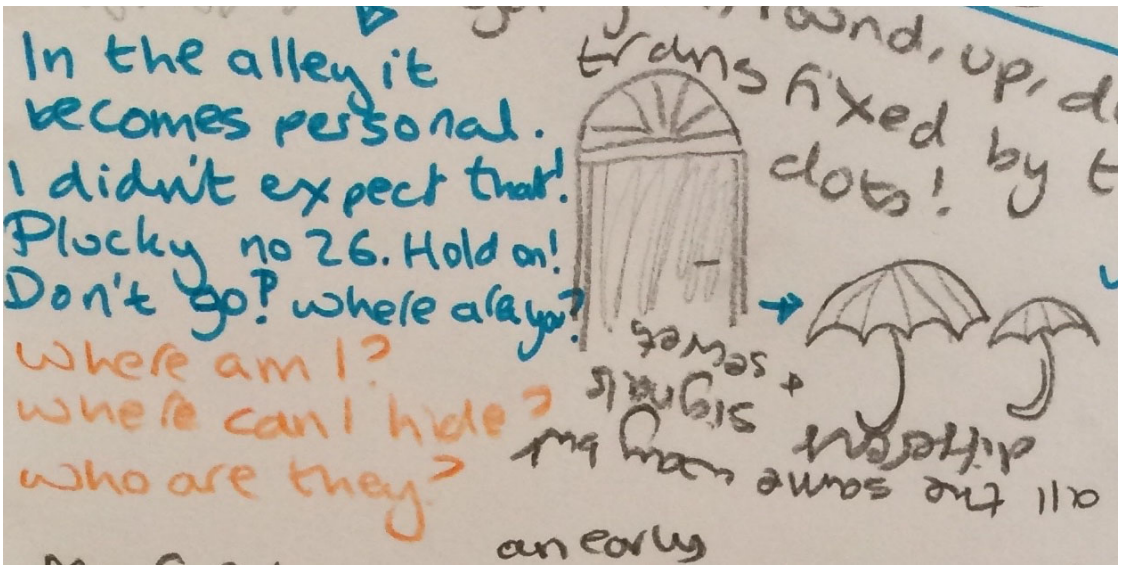

Figure 5.12: "In the Alley it becomes Personal". One participant forms an attachment to satellite number 26.

5.2.4.5 Summary

This experiment was successful in producing an infrastructural inversion for GNSS infrastructure. This is described in the theme of alienation in my analysis. Emergent from this theme was the idea of an environment; an space in which electromagnetic signals, architecture and participant bodies interacted to form a kind of signal ecosystem. While this theme emerged in several workshops, it was less present in the final workshop which was oriented specifically at signals and architecture. This is perhaps in keeping with the understanding of texture offered in the literature review; as concerning the indirect effects of infrastructure as understood through metaphor. In this way, a "field of signals" and the "city as braille" can be taken as metaphorical descriptions of this ecosystem and, thereby, the infrastructure's texture. These metaphors also begin to point to the ontological shift that is explored in more detail in the design workshops. The third key theme is the idea of dynamics, within which interactions and negotiations around surveillance, privacy and "personal" relationships with satellites can emerge.

5.3 Design Method

In this second half of the chapter I outline the findings from the second, design workshop method. This poetic method was intended as a diagnostic tool, exploring infrastructural texture through understandings of the centrality of the user in relation to both infrastructure and what I posit as more-than-human networks. Here sociotechnical practices of use are understood to intersect with the materiality and ontology of the technical infrastructure. I begin by describing, in brief, the outcomes of the first, developmental design workshop I undertook. Following this workshop, I iterated the technique to create a stronger focus on the kinds of agency we might understand the infrastructure, rather than the user, as holding. I then describe the two main workshops which form the bulk of the research data here. After each workshop description, I offer some reflection on workshop technique and brief analysis of workshop data before, again, offering a situational analysis of the data at large. The data here is the participant's design proposals, the way in which they were presented to the group and the discussion which ended each workshop session. All of these aspects are rich in creativity and metaphor.

5.3.1 Developmental Workshop

In April 2017 I organised a workshop in collaboration with The Culture Capital Exchange (TCCE), a research group I had worked with before. The workshop was advertised to all-comers, although in practice the majority of the eight attendees were design students who responded to a call out on local listservs. Working with my colleague Soomi Park, I spent an afternoon with this group asking them to complete an initial round of individual mini briefs then to work together in teams to approach a more complex brief. This brief specified a world in which different national GNSS systems (the American GPS, the Russian GLONASS, the Chinese Beidou) operate in competition. While at present, the majority of our GNSS-enabled devices can establish a position using signals from all these satellite constellations, in this future scenario, different national GNSS carriers

work to create rival notions of location and territory.

The results were mixed, three intriguing design proposals were produced, but I felt that they did not work towards the "answerability" [9] of my research questions. In other words, they did not strongly question a user-driven understanding of GNSS infrastructure. Instead they found ways of maintaining our current practices in the face the disruption offered by the design scenario. While this outcome is important to note, I was left unsatisfied and went on to iterate the workshop with a different design brief. In this section I describe the outcomes of the developmental workshop.

Of the three groups, one proposed abandoning GNSS altogether in favour of magnetic crystals which would be implanted in human bodies. Identifying a problem from the scenario that, by 2040, we have "become dependent on GNSS to orient ourselves", this group took inspiration from homing pigeons who use the earth's magnetic field for orientation and navigation. They understood this as a utopian scenario in which everyone would want this body-enhancing crystal implant.

Another group proposed using bioengineered bees to hack into the GNSS network, distributing signals in a way beyond the control and oversight of national GNSS carriers. They called this a 'Gambiarra Positioning System' after a Brazilian Portuguese word for an improvised hack. The bees would pick up GNSS signals from hives which functioned as antennas. People would then try and attract bees to increase their ability to use GNSS. This could be done by building a wildflower garden or, when on the move, by carrying a solution of sugar and water. This approach allows people to continue using a GNSS system which has been ringfenced to only work for GNSS operator countries. Without a GNSS of their own, Brazilians have to build a hack. Again, nature plays a role in the symbolism of this project.

The third group considered how a tourist would make choices between which national GNSS carrier to use when travelling to a foreign country, considering the potential advantages and disadvantages of each competing system. In this scenario, the current

navigation-driven practices around GNSS are again maintained, but with negotiated levels of access and implementation according to consumer choice. The tourist would not be the only one benefitting from this scenario, with the GNSS provider using this opportunity to direct people to sites which could be politically or economically profitable for them.

While these proposals were all interesting in their own right, I felt that they missed the mark of my research questions. There was no significant shift away from the user as the focal point for sociotechnical practices. In fact, maintaining access to existing user functions was a key theme in all three projects. Indeed, the material limits of GNSS were radically bent out of shape to allow for a continuation of existing practices. The bee project in particular, while beautifully described, stretched the technical functionality of GNSS beyond something recognizable.

In response to these concerns I decided to re-iterate the workshop with a different participant group and a different scenario. In the next iteration, I used a brief that was more focussed on the active role which infrastructure plays in GNSS practices. I proposed a scenario where, due to developments in artificial intelligence, satellite constellations have begun to identify and act on their own concerns.

Following this experience, I also wanted to widen the participant profile to include engineers as well as designers. I had been troubled by how far some of the projects had moved from what is currently possible with GNSS. Via the influence of Ratto's critical making techniques, I had wanted to emphasise the materiality [10] of the technology. In the previous method in the Barbican I had been able to do this through having participants observe GNSS signals' interactions with buildings. Here, however, there was no opportunity for a similar re-enforcement of the technology's material base and limits. I therefore decided to pitch the next round of workshops at engineers, particularly engineers with some experience of GNSS. My intention was that this group would already have an idea of the material limits of GNSS technology (or failing that, an idea of the technical processes behind designing and building a complex system). This group

would, therefore, be more likely to propose less abstract proposals, thereby giving GNSS infrastructure a more credible role in future practices.

5.3.2 Engineers' Workshop (Queen Mary)

After several approaches to external, engineer-facing organisations were rebuffed, I decided to host two workshops at my university, inviting engineers from organisations around London. These workshops took place over two evenings in July 2017. Each workshop was delivered in a condensed form, lasting around two hours. Calls for participation were made both internally and via external mailing lists which targeted engineers. These included several London-based hackspaces, the Royal College of Engineering and the Royal Society. In an attempt to encourage participation, attendees were offered 10 pounds each to cover their travel expenses. We received ten participants in total, six of whom were internal to Queen Mary (from the Electronic Engineering and Computer Science department), one artist and masters student from Central St Martins and three external engineers. One of these engineers was a chemist and two worked directly in the GNSS industry; one for Airbus who are developing the European Galileo constellation and one who works specifically with satellite antennas.

Over the two evenings, participants formed small groups of two or three and worked in response to the brief described below. As before, they had to create an artefact to convey their concept. I was assisted in this workshop by Raphael Kim, a colleague at Queen Mary who trained under Antony Dunne and Fiona Raby at the RCA. He gave a brief presentation on speculative design at the start of the session and supported individual groups with the development of their concepts. Their projects are described below.

5.3.2.1 Scenario

The scenario given to the participants was as follows. Working in groups, they were asked to produce an artefact, interaction or scenario which would exist within this world.

2040 Satellite Systems Become Self-Directing

> After a series of technical advances and budget cuts on earth, in 2040 it is decided to remove ground support from the world's GNSS systems. Technical advances in machine learning mean that the system can maintain and correct itself to the standards required to support existing uses. The corrective model has been trained on existing use data (in terms of physical environment - terrestrial and extra-terrestrial, time, terrestrial navigation, military support). After 10 years, the system has continued to evolve and begins to identify decide on and work to its own goals, both on the earth and in space.

With this scenario I wanted to make the focus on infrastructure more explicit, concentrating on what role GNSS infrastructure might play in the future, both in relation to humans and beholden to itself. Artificial intelligence offered a useful conceptual bridge [1], creating a way of understanding a radically different future technology through one which exists in the present.

It is worth noting that the idea of using Artificial Intelligence first came from a comment made in the discussion at the end of the previous workshop, where a participant said:

> "My initial thought from this scenario was that the artificial intelligence singularity had happened and the satellites had evolved and were talking to themselves now."

In building on this proposal, I intended that this scenario would act as a strong prompt for participants. By making them consider the influence of infrastructure in the ways in which their practices are formed, I wanted to create alienation from user-centered design techniques and user-centered understanding of everyday practices with GNSS. This scenario was thereby intended to strongly encourage participants to think about GNSS from the point of view of the infrastructure rather than the user.

Five projects emerged from the workshops. I will describe each project in brief, noting what the participants proposed, the directions which their work pointed in and, briefly, what insights can be drawn from them. I will then treat the data from the projects and discussion all at once, in a thematic analysis at the end of this section.

5.3.2.2 Project 1 - Figure 5.13

Figure 5.13: The model from Group 1. A 'Time-o-poly' board containing tech companies and time-associated brands which satellite constellations compete to acquire.

This project, which the group titled 'Time-o-poly', posited that in the future:

> "The autonomous GPS satellites [would] use their influence over timing signals and other things to manipulate stock markets and gain capital. They would then go on further to manipulate the world, possibly buying the factories that build the satellites so they could upgrade their capabilities."

Each rival satellite system (GLONASS, BeiDou, Gallileo) would also be trying to

accumulate wealth and resources, leading to a competition process which this group described as "time-o-poly", depicted through a monopoly-style board in which rival GNSS systems compete to purchase tech companies and famous brands. The brands, such as *Rolex* and *Citizen*, speak to the important role time plays in the operation of GNSS systems and their ability in this scenario to defraud the stock market by inserting delays in the timing of trades. The accumulation of brands also plays a public relations role, influencing the human population who continue to live and work on the earth as in the present day.

The project was described by the team of participants as a "hyper-capitalist dystopia" in which the satellite systems, initially driven by a desire for self-reliance through securing assets on the earth, enter into competition for resources. The sense of competition also extends across national boundaries, with the participants suggesting that the European Galileo system may try and meddle with American stock exchanges, while the GPS system may concentrate on Russian exchanges.

The project proposed capitalist accumulation (made highly explicit through the use of the monopoly board) as a way to speculate about the possible behaviour of self-directing GNSS. It was also noted that, despite their increased power, the satellites still felt the need to cater to the existing human population through branding and public relations exercises. The project also focussed on and developed a lesser known function of the GNSS network; syncing cross-time-zone financial trades. It uses the metaphor of competition between GNSS systems to re-frame the infrastructure as a composed of competing parts which presently collaborate, but may easily return to a state of competition, as they were in their early incarnations as primarily military technologies. The link between GNSS infrastructure and economic development is also clearly present through the use of the monopoly board, as is a focus on time rather than space. While many of the other projects focussed on practices of mapping and creating space, this group focussed on GNSS as a creator and arbiter of time, with the potential for asymmetrical power and exploitation which that ability can create. In these ways, the prompt was able to use

metaphor to probe lesser known textures of GNSS infrastructure and its operation.

5.3.2.3 Project 2 - Figure 5.14

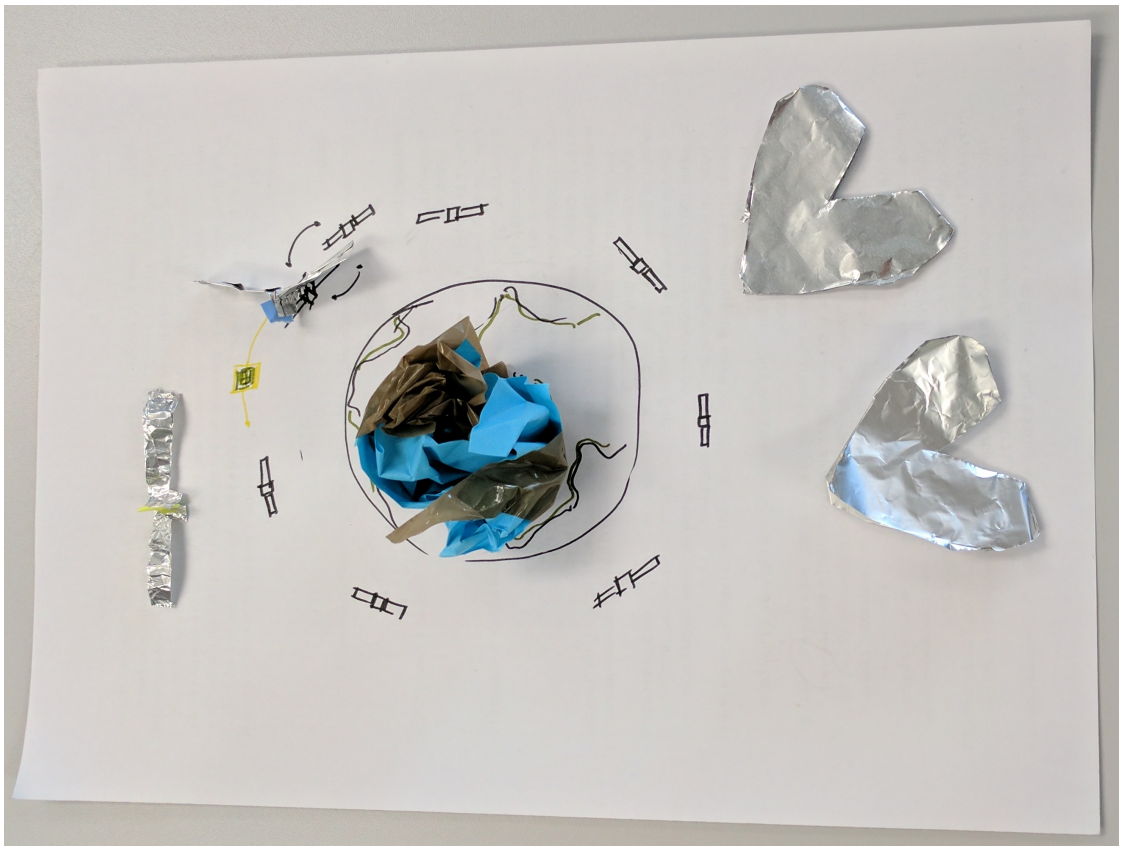

Figure 5.14: Model produced by Group 2 representing a mating dance between two satellites. Note the silver love hearts on the right.

The second project described a set of relations between satellites in which the ground system and other resources on earth become less important. Rather, the satellites: "become their own species" and "start to orbit together sort of like flocks of birds". To continue the existence of their species they decide that they need to breed which they do by finding a partner and "take bits off each satellite and stick them together to form a new satellite". This exchange is preceded by a kind of mating dance in which satellites move around each other, dipping their solar panels, to decide if a given satellite is a suitable partner. At the same time, the satellites "have a caring feeling towards the earth because that's where all their materials come from." The satellites "are looking

after [the Earth] unlike the humans that were there before them". So, in this scenario, the focus is firmly away from human beings. When pressed on the presence of humans in their scenario, this group said: "there might be some humans around but they're not doing very well, it's all about satellites now."

When asked why the satellites would partner off to breed, the group said it would come from a sense of their own mortality, an awareness "that they can't live forever." When pressed on how the emotional aspect of finding partners and mating might exist for satellites, the group said: "Isn't [emotion] just humans trying to survive, so it's the same thing." The artefact produced by this group was a drawing of the earth surrounded by flocking satellites.

This scenario, therefore, gives a different feeling from the sense of competition described by group 1. The idea of collaboration is strong here, offering a different pole through which to understand the possible motivations of an independent GNSS infrastructure. The metaphor of satellites as a bird-like-species focussed on survival and propagation marks an interesting break from the anthropomorphisation of technical systems to understand their motivations. The satellite network here does not find it necessary to collaborate with the humans on earth; it is not hostile towards them, but instead unconcerned, except through an abstract sense of care and guardianship. The satellites maintain an interest in the earth, but have moved beyond it, finding themselves able to reproduce in space. This project, therefore, posits a decisive shift away from the human user, offering a conception of the infrastructure that would be more at home in a nature documentary than a technical description.

5.3.2.4 Project 3 - Figure 5.15

This project was proposed by a participant who wanted to work individually because of her concerns over her level of spoken English. She was inspired by the different ways in which signals penetrate buildings and paper models to represent architecture which

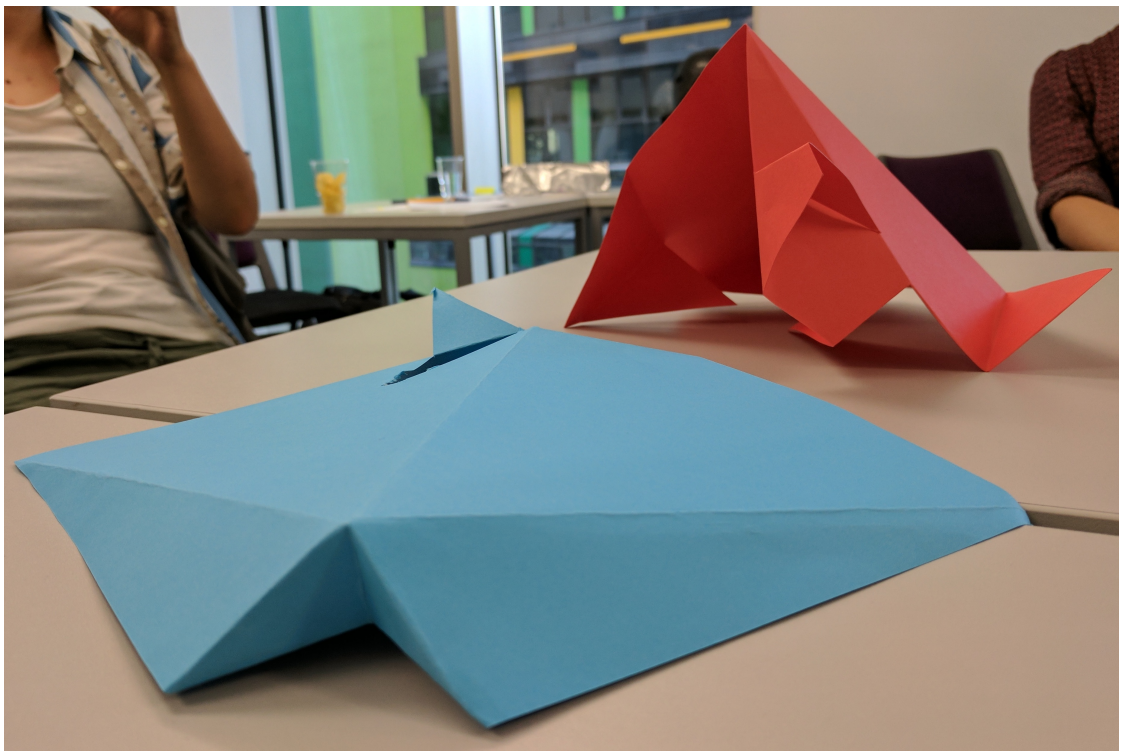

Figure 5.15: Group 3's potential future building which would deflect and absorb GNSS signals according to the owner's preference.

could block or concentrate the presence of GNSS signals. She judged that this would be particularly important in a future in which satellite systems would follow their own areas of interest rather than following human concerns.

This project directly addressed how humans would exist in a future world in which satellites have grown more powerful and unpredictable. It also strongly harks back to the themes which emerged in the walking workshops. Human builders can use architecture to provide a sense of gradation and control in a world of blanket signal coverage. The project points to how human agency might be contested and emerge in a more-than-human realm.

Figure 5.16: Model from Group 4 showing a system architecture for GNSS satellites and humans. The human traits are described at the bottom of each side of the model, with the satellite traits at the top.

5.3.2.5 Project 4 - Figure 5.16

This project offered a system architecture of the ways in which a self-directing satellite system might interact with a stack of other artificial intelligence agents and, ultimately, their human directors. This project therefore incorporated a more traditional under-

standing of artificial intelligence as something used to improve the speed, functionality and scope of an established computing task.

The group focused on the agricultural sector. In this case, GNSS has a specific function to give a precise resolution in the data used to optimise crop yield. The humans directing the infrastructure have a more varied set of tasks and interests, but lack the precision and perspective of the satellite network. This project, therefore, is firmly about collaboration, both between satellite systems in the sky and with the human element on earth. The goals which these satellites have identified are firmly grounded in the tasks and training given to them by humans. They are still working for the benefit of stakeholders on earth. The collaboration between humans and infrastructure was described in detail by the group, especially in the idea of a "hierarchy" of "many layers" between the satellites and humans. Each of these layers would likely be automated and communication between them may result in a "Chinese whispers" effect, "if no-one knows what the other layers are doing, apart from maybe one up and one down".

This group, therefore, imagined a situation in which satellites did not "go off on a complete tangent", but rather, "their machine learning is always going to stick to roughly what they were told initially. They've been told: Do a really good job", whatever that job may be. Humans, therefore, are ultimately still in control of the infrastructure, and this aspect of the scenario makes this group unique. They did not see the potential for 'tangential' behaviours in the brief, but rather explored the implications of how the proposed scenario might work within existing practices.

To convey their idea, the group build a cone shaped system architecture with the satellites at the top and the humans at the bottom. The architecture was organised through the themes of 'size', 'quantity' and 'focus'. The four faces of a model depict a system architecture of how humans and satellites interact in Project 4. In each case the satellite layer is at the top and the human layer is at the bottom. In between a word marks the shift from satellite to human perspective (see 5.16).

The metaphor here is that of GNSS used to help increase agricultural production. This represents a more traditional understanding of the infrastructure as a technical solution to a human problem. GNSS acts as a tool, something that extends the reach of human capabilities. It achieves this unproblematically, with little friction. The friction that does exist is primarily between elements of the system, as some confusion emerges in between different layers of the technical stack. The only obstacle to the projects successful outcome (increased production) is, therefore, ease of communication across technical platforms. In this way, this project can be read as a more traditional 'engineering' proposal, where the goal is unambiguous and the discussion is around how best to achieve it.

5.3.2.6 Project 5 - Figure 5.17

The final group also offered a utopian scenario in which satellites acted as "guardians" over the earth. The acts of care carried out by the satellites included defence against existential threats such as climate change or the outbreak of a hostile disease or bacteria. They are motivated partly through a historical connection to the ground system on earth which they view affectionately, however, in this scenario, the ground station continues to carry out a functional role. The group noted that "we didn't talk about more ambitions of the satellites themselves, but just their existence" and the maintenance of that. In order to become more effective, the satellite network may want to improve the data they collect on the earth or otherwise expand their capabilities, but, again, their motivation is primarily to maintain their current level of existence rather than take on a new role. In this scenario, the different satellite systems "co-exist rather than collaborate" both with humans and with each other, again like a new kind of species.

This group prepared an artefact showing the earth and sky with satellite trails represented by foil and the ground station represented by an image of a pagoda cut from the craft materials.

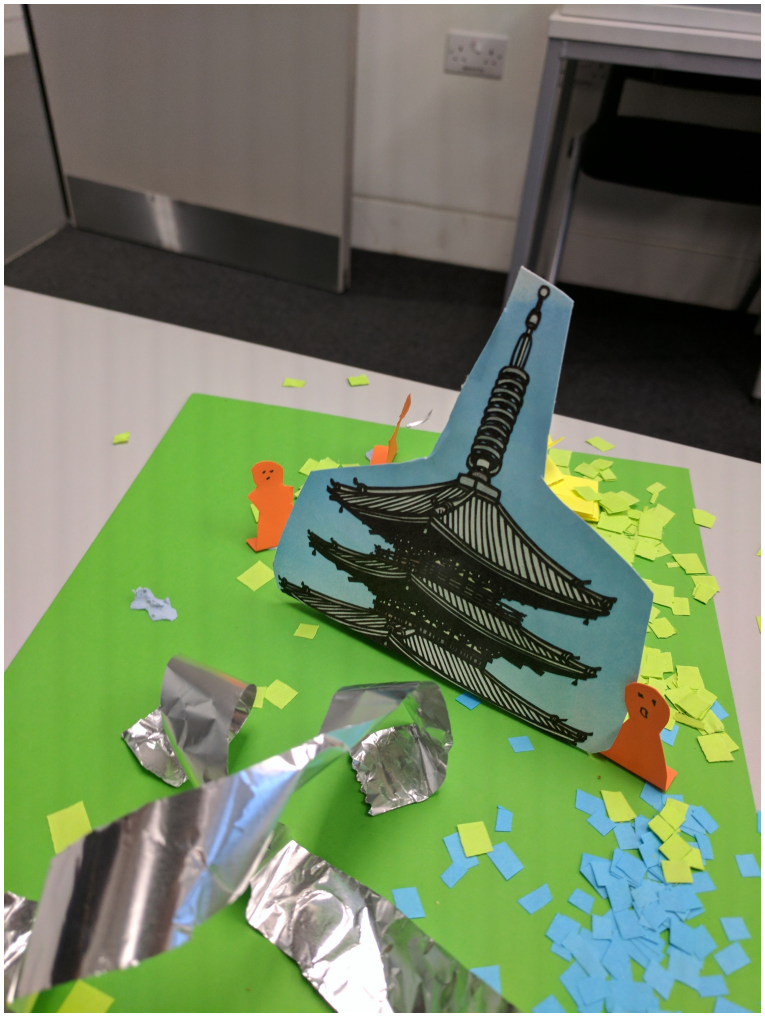

Figure 5.17: Group 5's model to illustrate the earth which the guardian satellites oversee and take care of.

The metaphor here was one of satellites as an external power with near-divine qualities to guard and protect the earth. The satellites don't act at the bequest of humans, but they neither do they compete with them, rather they are understood as two different species occupying the same site (the earth and its surroundings) and holding the broadly similar aim of maintaining a healthy environment. That said, the motivations of the satellites themselves are a bit more ambiguous, they maintain an affectionate connection to the earth and have some stake in its continued health because of the importance of their 'ground station'. This interest is taken more to mean maintaining the status quo between humans and satellites rather than intervening to change it. The underlying

metaphor here is therefore one of technology as a protective and potent force which can help overcome existential threats and crises on earth. The satellites continue to play this role even though the specifics of their motivation may be unclear.

5.3.2.7 Themes

In my reading of these five projects, several overarching themes emerge. These can be seen as structures though which to read understandings of GNSS infrastructure as born out through their textures, ideas that are consistent across the groups' differing uses of metaphor. This analysis is relevant both for grounding the metaphors used by participants and understanding how poetic methods work to prompt those responses. An analysis of these themes allows us to begin to unpack shifts in understanding around more-than-human networks.

The overarching themes are: The concerns identified in building the world; The motivations of the satellite infrastructure(s); and the satellites' relations with other actors in this world (humans, the earth, rival satellite constellations). I will approach each of them in brief below.

World Building

Following on from my experiences in the developmental workshop, where participants spoke about relationship between utopia and dystopia as a literary device, I decided to make this tension explicit, suggesting it as a point of orientation at the start of the workshop. This dichotomy became relevant for several groups, with two stating specifically that they did not want to create a dystopian scenario. For other groups it was more ambiguous, Group 1 (time-o-poly) described theirs as a utopia for "the one satellite system that wins" and a dystopia for the others. Similarly, Group 4 who suggested an automated agricultural system noted that theirs had dystopian elements for people who lost their jobs because of automation.

Having chosen the direction of their scenario, each group had a set of building blocks through which to understand what would happen in their world. Often these were not limited to features of the satellite system. Both Group 1 and Group 4 acknowledged that they gave as much weight to the AI part of the brief as to the GNSS part, using both to imagine the organisation of their world. Group 4 understood that, through machine learning, the satellites would be told:

> "Here's some outcome, try and achieve it as best you can and that outcome is set by humans, so it's probably a human type thing."

Their starting point was, therefore, that satellites would continue to follow set tasks. It meant that, in this world, humans continued to define the system and set the terms under which satellites operate and profit from the results.

For Group 2, another existing system acted as a model; the animal kingdom, particularly flocks of birds. Understanding satellites as "a new kind of species" meant that they were not limited by their programming or human concerns, but would instead exist independently of humans, build their own social order and aim towards their continued, successful existence.

For Group 5 the physical capabilities of the self-directing satellite system became important. This group proposed the satellites as a group of celestial guardians and wondered if, in this future, "satellites can manipulate physical things", allowing them to protect the Earth from asteroids or take actions to mitigate catastrophic climate change. For this group, the positioning of the satellites was clear, but the ability of satellites to shift from observers to actors was more ambiguous.

World building is the starting point of these scenarios; the point at which groups decide the model for their scenario, (be it based on human concerns or animal behaviours) and the physics of that world (based on what satellites are capable of). From here, the next theme to emerge is what motivated satellites in the actions they take.

Satellite Motivations

The question of what motivates satellites to act in the ways described in the scenarios was constantly below the surface. It combines with larger questions over how humans can conceptualise the motivations of a more-than-human system and what this shift brings to the research process. These larger questions will be addressed in more detail in the discussion chapter. For now, the question of what motivates the satellites is an important lens through which to approach the metaphors described in participant scenarios.

For several groups, the satellites' motivations existed as an extension of human behaviours and concerns. This was addressed literally by Group 4 who proposed that a self-directing satellite system would continue to work in an earth-facing functional infrastructure. Here, the task set by human engineers provides the motivation for the satellites' behaviour. For Group 1, human behaviour provided a clear model through the accumulation of capital and resources. Here, the satellites were understood to be following the logic of capitalism, originally amassing resources for self-preservation, but then working in a competitive environment with other satellite constellations. This was described expressly by one member of the group as a "typical human desire which is to make lots of money and defraud the stock exchange". Group 2 proposed that satellites would enter into monogamous relationships and produce offspring. The links with human behaviours are clear here and made even more explicit by the references made by this group to the potential 'emotional' aspect of satellite relationships. Reflecting on this trend, a participant from another group said:

> "I think that the human brain obviously thinks things through in a human way. So, your scenario, you came up with kind of a monogamous relationship between satellites. I can't see any reason why satellites would choose that form of interaction."

Thirdly, both Groups 2 and 5 offered the idea of satellites as guardians of the earth. This is another kind of human behaviour, albeit, for these groups, a failed one. The

satellites are "looking after [the earth], unlike the humans who came before them".

All these groundings for satellite motivation understand their goals and motivations in recognisable terms. While this is perhaps unsurprising given the machine learning aspect of the design brief, it is still notable that no-one said: 'I don't know why they're acting this way, they're satellites.'

Beyond these specific human-like motivations, the main driver for the actions of the satellites was self-reliance and self-preservation. This was shared across all groups, except for Group 4. When this theme was raised in the discussion, one participant said: "I think we just took that as a given". For another participant, "continuous existence [was the satellites'] main focus". For this participant's group, survival was the key point of meaning: They "didn't talk about more ambitions of the satellites themselves, but just their existence." For this to happen, the satellites must be aware of their own mortality. While this awareness lead to competition Group 1, for Group 2 it lead to collaboration:

> "They decide that they're not going to live forever and they're looking for a way of surviving and maintaining themselves to stay alive and they realise to do that they need to work together."

Existential threat was therefore the base line for the majority of satellite behaviours. First and foremost, satellites were understood to want to continue existing, and exist successfully. From there, the groups could abstract different types of behaviour which might best allow their satellites to exist and thrive. These motivations did not mark a strong break from familiar models, be they human ones, or ones from other species, but their re-contextualisation into GNSS systems suggests another way of understanding these infrastructures. They can be more than a collection of technical protocols and begin to resemble a series of intentions and actions.

Relations with Other Actors

To realise these intentions and actions, the satellite systems had to engage to various

degrees with other actors in the future scenarios. This theme speaks strongly to the technique's role as a diagnostic tool to get a sense of the texture of GNSS infrastructure. For Group 2's breeding satellites, this interaction was minimal, manifesting as a fond but disengaged attachment to the earth.

At the other end of the scale, Group 1 and Group 4 developed scenarios which placed satellite systems strongly within affairs on earth. For these two groups, interacting with humans took up a great deal of the satellites' energy. The competitive systems offered by Group 1 remained concerned with gaining public approval for their actions through buying successful brands and incorporating them into their activities to "give a good public image" when "people look up on their binocular phones". The satellites are, therefore, not entirely free of earth and earthly concerns, but are rather understood as concerned with the accumulation of capital and resources. In this role, much as with the watching satellites from the walking method, they begin to act as stand-ins for the organisations and attendant infrastructures that profit from the actions of GNSS infrastructure.

The interaction between satellite systems and structures on earth was addressed in a more detailed way by Group 4. Their stack of complementary artificial intelligences proposed a highly complex and perhaps ambiguous "fifteen levels" of artificial intelligence. This infrastructure should be taken as a whole, working toward the same determined goals, albeit allowing for complexity in communication and goal-setting between layers. In this system, satellites offer perspective through the collection of highly precise data about what is happening on earth. They focus on "details" rather than the human at the other end of the stack whose role is more general. From the satellites' point of view, humans are another element in a wider architecture which they themselves are also part of. For this group this dynamic was represented in their system architecture model, depicting the means of communication across the stack. Here, therefore, the shift to more-than-human networks becomes primarily a question of the range human motivation. The stack of artificial intelligences has its own internal frictions around com-

munication, but this is more of a technical question around calibration than something that effects the overarching intentionality of the system. The resulting more-than-human system is still ruled by human concerns and extends the power of the human driver. This metaphor, therefore strongly suggests an idea of GNSS texture as something firmly in the control of a wider, human led organisation which is working toward given, unambiguous outcomes.

Group 3 took a markedly different approach to the scenario. This group's single participant worked from the human point of view and suggested architecture as a way in which people could become more empowered in the face of powerful self-directing satellites system. The buildings she proposed could either block or amplify GNSS signals depending on what was required. She compared this to what in Chinese is called a 'no-human plane' (a nice touch given the focus of the workshop) and suggested understanding the buildings in a similar way to planes which can block signals and not be followed by radar. Such stealth or stealth-drone planes can move through the air untouched by the ecosystem of signals that surrounds them. In this case, buildings could offer the same invisibility and ability to operate away from the influence of GNSS actors. The idea of GNSS' relationship with architecture is covered in detail elsewhere in this thesis, but here it offers a way for people to respond to a loss of control of the electromagnetic realm and the influence of self-directing GNSS systems.

5.3.2.8 Summary

In relation to the research questions, this round of projects leveraged metaphor to offer some insights for the nature of more-than-human networks. It did this through an examination of the kinds of world that may emerge if the GNSS network had a clearer agential power. In this way, as well as critiquing sociotechnical understandings in relation to practices around GNSS, the projects can be understood as exploring the texture of 'intra-action' between user and infrastructure and across emergent networks.

Of the five projects, only Group 4's understood GNSS as a tool firmly under human control. Here a more powerful incarnation of GNSS was used to maximise crop yields. The infrastructure's increased agency was directed towards the successful completion of its set task. The idea of the infrastructure as tool was also present for Group 1, but here the rival GNSS networks competed to becoming the most successful tools. Human intentionality was incidental in this example, becoming something the GNSS networks used to serve their interests.

Group 3's work, in which humans used architecture to control the flow of GNSS signals, offered a scenario in which the reach of GNSS signals was understood as one pole in a power relation with humans on earth who engineered their buildings to direct the flow of signals. Here, the built environment is used as a way of negotiating agency in a more-than-human network.

Finally, Groups 2 and 5 offered understandings of the GNSS network which were defined by their distance from the human. For Group 2 the satellites become a bird-like species with little interest in life on earth. In project 5, the satellites do take a keen interest in life on earth, but their power places them at a distance from humans. They become more like guardian angels who intercede on earth, with the gulf in power meaning that humans have little ability to contest or shape the satellites agency or actions.

Across these projects, therefore, we can learn something of understandings of more-than-human networks. The majority of projects suggested that they would emerge through negotiations of emergent agency between humans and infrastructure. Typically, infrastructure was understood as intrinsically more powerful than the human realm, either through its role as a guardian angel, or through its ability to direct human economic activity for its own benefit (as for Group 1). Group 4 was a strong exception to this. The role of the human in the emergence of infrastructural agency, even if only as a field of operation, remained strong through the projects, with only one project suggesting that GNSS infrastructure would have little interest in the human realm.

At the end of this experience I was encouraged, by the methods ability to address questions of intra-action in more-than-human realms and I decided to repeat the workshop using the same future scenario.

5.3.3 Designers' Workshop (Future Cities Catapult)

Following on from these experiences, I wanted to try working with designers again. Running another designers' session would give me a comparison group using the same scenario. Also, by using a greater range of participants, I would get a better sense of how transferable the technique could be. I therefore organised a final workshop at Future Cities Catapult in London. This organisation is one of several government funded innovation hubs working across different technical applications. This workshop took a similar form to the Queen Mary workshops. The eight participants were recruited from the resident designers at Future Cities. This group, therefore had strong design experience, some technical experience in working with GNSS technology in urban design projects, and a willingness to think creatively in their workflow. Like the previous workshop, this was run with Raphael Kim who provided logistical support and assisted participant groups in developing their concepts.

5.3.3.1 Group 6 - Figure 5.18

The first project imagined a future in which satellites would be able be able to make everyone's location and movements publically known. This blanket tracking is caused by satellites following their existing programming to its logical conclusion, a move to "maximise their utility function". Everyone is covered by this tracking regardless of status or position. In addition, "the satellites will be trying to take justice in their hands. So, they would be sending messages to peoples' phones whenever they're doing patterns which are irregular". However, some people object to this blanket surveillance and cover their heads in corrugated aluminium foil and coat their devices in concrete to

Figure 5.18: Group 6's artifacts created to illustrate their 'silverheads' scenario.

prevent the satellites from tracking them. These 'silverheads' are highly visible on the street because of their strange attire and are regarded with suspicion by the majority of people who "really agree with the tracking system". Figure 5.18 shows a 'silverhead' with his head covered in foil and his device coated in concrete to frustrate GNSS tracking and direction. His sign reads: 'I refuse to be seen by the machines' and his phone displays two alerts: 'Where are you going?' and 'Irregular Movements Detected!'

As in Group 3's architecture project, the key concern here is with the balance of agency and control in the relationship between human and infrastructure. A group of people take drastic steps to maintain their privacy and resist the "justice" dealt out by the GNSS network as it tries to control behaviour. In another interesting layer, the group discuss what kind of effects the implementation of this system would have socially, with the silverheads being the subject of suspicion and ostricisation by their fellow humans. This group, therefore, uses metaphor to explore how power-imbalances

in emergent technologies can lead to social friction.

5.3.3.2 Group 7 - Figure 5.19

Figure 5.19: A 'we love satellites' badge created by Group 7.

The second group had some difficulty agreeing on a single scenario, instead proposing a series of short ideas. Firstly, they proposed a docking system where around 50 satellites could link together to save fuel and give themselves a longer lifetime. The gaps in overall GNSS coverage which this would create could be mitigated using a secondary network of low orbit relay drones.

In a second, co-existing scenario, they proposed that the satellites could hack into an internet relay and amass data about the population below through their social media feeds and online activities. Equipped with this knowledge they would make decisions on "which person is a good person and who is a bad person", using this information to "create a relationship with the people on earth" through limiting the GNSS signals which would reach "bad people" and increasing the signals which would reach "good people". The satellites' advanced artificial intelligence would be able to see through any

human attempts to doctor their internet record to get better signal.

A third, perhaps parallel scenario involves "a kind of fandom around satellites." In this scenario, people who were known to be "satellite fans" would also be able to receive a better signal. Figure 5.19 shows an 'I Heart Satellites' badge worn by satellite fans. The group also suggested ways in which the satellites might begin to charge for the use of their signal, to generate funds to support their continued operation. The pricing model here would be similar to *Uber* and take into account times of increased demand by adding a surge charge.

This group came up with several metaphors, but, in a similar way to the previous group, they hinge around the social asymmetries which are created by an unevenly distributed technology. The GNSS infrastructure is extremely powerful here, with the ability to judge humans and tailor the operation of the infrastructure according to those judgments. In order to be active and enfranchised in the decisions that effect them, humans must attempt to curry favour with the satellites by showing devotion. The satellites are therefore understood as distant and powerful agents.

5.3.3.3 Group 8 - Figure 5.20

The third project sees satellites take up a role as guardians of the earth, preventing humans from overexploiting natural resources. The satellites would work to protect numerous resources, but the example described in detail by the group was fish stocks. Through their ability to calibrate mapping practices, the satellites would "protect" areas under environmental stress by making them invisible to navigation equipment. These "safe triangles" would be dynamic and could shift as resources regenerate and become more plentiful again in certain areas.

Figure 5.20 shows a storyboard describing how satellites will de-mark space for humans to live and work in, allowing other areas time for environmental recovery. It is unclear why these "environmentalist" satellites act in this way rather than "for their

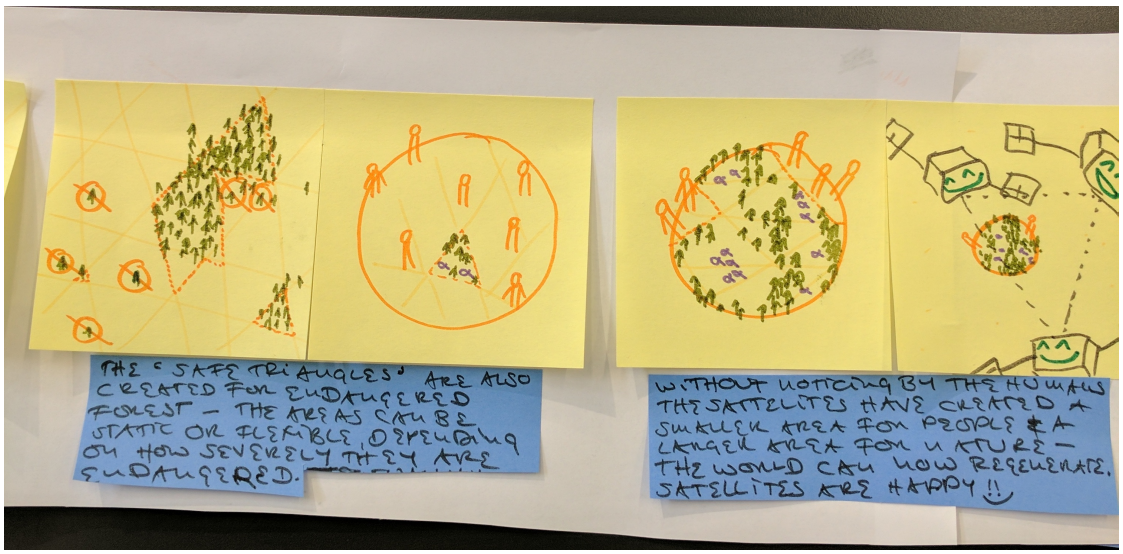

Figure 5.20: A storyboard to illustrate Group 8's project.

own advantage". Besides the idea that "if the world collapses, they will collapse", the group stated that they "believe in the greater good of the satellites". It is worth noting that, to keep people away from a regenerating area, the satellites may also deceive them, intervening in the map to imply there is danger in that area, perhaps "quarantine" or "viruses."

We have already seen satellites occupy a role of earth guardians in the previous workshop. What is different here is a more developed idea around how they would operate within that guardian role. Crucially for the idea of more-than-human networks, they frequently work against human interests to achieve the guardianship of the world, deceiving them through modified mapping practices. Here, humans are seen as a powerful force that must be directed and optimised for the good of the whole. This is an interesting inversion of the scenario proposed by Group 4 in which, GNSS infrastructure will engage in environmental terraforming for the specifically human goal of increasing agricultural production.

5.3.3.4 Themes

Many of the themes which emerge here also fit into the thematic analysis that emerged from the engineers' workshop. However, some new and modified themes are also present.

In both Group 8 and Group 6's projects, satellites act as solution-makers for the wicked problem of climate change. However, for Group 8, their tool for action is more clearly defined. They will leverage their own role in creating maps and demarcating territory to isolate and preserve certain sites and habitats. There was some discussion in the group around how they would successfully demarcate space, at which point they suggested isolated islands would be the preferred preservation habitats. The innovation here is really the idea that maps and mapping practices have the power to influence life on earth by making certain areas desirable or inaccessible. A parallel was drawn by the group between their idea and older maps which may find unknown areas inscribed with warnings such as 'here be dragons'.

This project saw the satellites develop judgments about which territories to preserve and maintain. The implication here being that humanity is a destructive force that must be carefully managed by an external agent. A sense of intervention in human affairs was also strongly felt in the other two projects. Indeed, both these projects went further than any described before to propose the idea of the satellite network making moral judgments about people. In Group 6's project, satellites make everyone's movements transparent and publicly known. At the same time, through "their own code of ethics" they send "messages to peoples' phones whenever they're doing [movement] patterns which are irregular".

There is some slippage here from the way in which the GNSS system works at present. Satellites do not actively track movements, that is done elsewhere, either in an operating system or a smartphone application. However, while the technical understanding is a misnomer, the idea of being tracked and the lack of control which that displays appears to be a strongly held concern within infrastructural texture. So, while idea of an artificially

intelligent satellite network making value judgments about peoples' behaviour is a new theme in the speculative design workshops, it harks back to the theme of surveillance and privacy in the walking workshops. The idea of hiding from external tracking also makes a strong appearance here through Group 7's silverheads' concrete and aluminium protection. This idea of grabbing personal power back from a totalising system was also felt in Group 3's signal directing architectural forms.

Judgment, exerted on humans by the satellite network, was also a strong theme for Group 7. Here it was realised through the separation of "good and bad" people through the satellites' monitoring of browsing data and social media history. The consequences of such judgments would be felt directly (rather than through public exposure and censure) when the satellites choose to provide or withhold their signals depending on their judgment. In another twist, if a person is a "fan" of the satellites then they can also receive good signal. People can signal their fandom by displaying some of the "merchandising around satellites". Therefore, if someone can prove themselves a follower of satellites they can receive better connectivity. Satellites, therefore, become an external reference point for behaviour on earth, occupying an almost divine role of bestowing favour on certain people and exerting judgment on others.

5.3.3.5 Summary

In summary, power relations and the negotiation of agency emerge as powerful themes through the metaphors developed by the groups in the designers' workshop. In all three cases, the GNSS network was interventionist in the way in which human activity was organised. Two of the three projects gave further thoughts on how such a set of interventions would act across human society, creating friction and conflict between groups.

This crop of projects, therefore, understood more-than-human networks as something fractious and many-layered, rather than just being about the meeting of the human and

the infrastructural realms. The presence of human actors remained strong and, more so than in the engineers' workshop, most ideas produced here were described through their effects on humans. In relation to the research questions this was a mixed blessing. The designers' workshop did not, perhaps, move as far away from user-centered ontologies as I had hoped, but, at the same time, the continued strong presence of humans in the projects provided a lens through which to explore infrastructural texture.

5.3.4 Situational Analysis: Design Workshops

In this section I consider the speculative design workshops as one complete dataset. To recap, the material for this analysis is the 8 projects proposed by 18 participants In the engineers' and designers' workshops. The data from the developmental workshops is included in a reduced form, but much stronger weighing is given towards the themes which emerged from the later workshops. In keeping with the drive for accountability in the research process [4] I have also included some of my theoretical starting points and concerns relating to the staging and participant pool in the workshops.

As before I list all the themes, reflections on staging and relevant actors outside the immediate research process. I then show the map I produced by considering their inter-relations (see figure 5.21). The themes are:

Utopia, Dystopia, Animals, Network, Mapping, GNSS, Human, Earth, Researchers, Motivation, Participant Training, Authorship, Innovation, Architecture, Dependency, Branding, Surveillance, Resistance, Accumulation, Survival, Pro-creation, Craft materials, Artificial Intelligence, Science Fiction, Climate Change, Environmentalism, Globalism

In the subsequent analysis I describe the overarching metaphors (or conceptual bridges) through which the participants situated human and infrastructural interactions. I then describe four key themes that emerged through those inter-(or intra-)actions. These themes are my readings of the infrastructural texture that emerged from the work which

the method did to shift understandings about the prominence of the user and the presence of more-than-human networks.

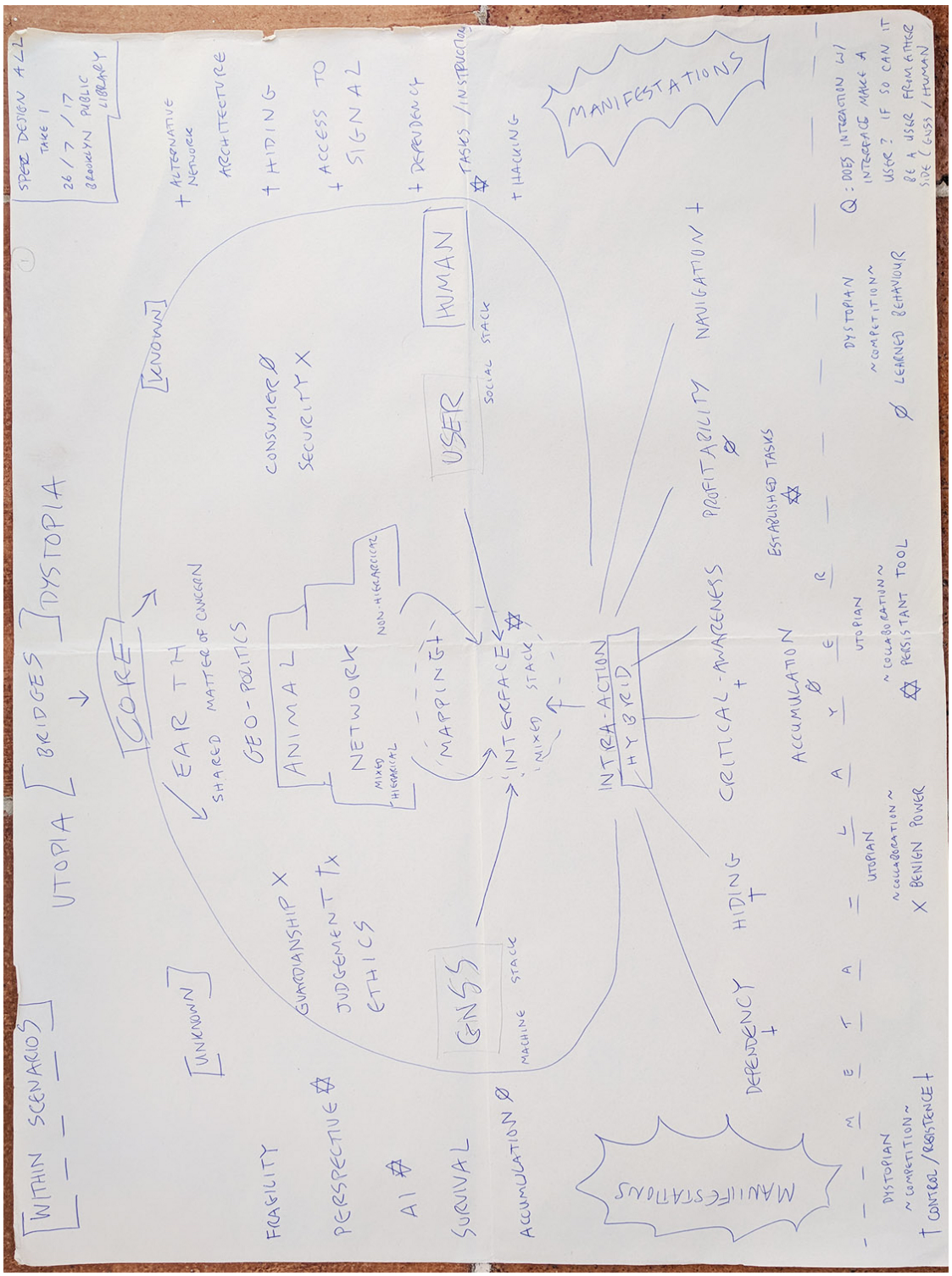

Figure 5.21: Situational analysis of the speculative design workshops.

5.3.4.1 Authorship

I begin the analysis by drawing attention to the authorly quality of the data produced here. The idea of authorship can point to how these methods manifested in relation the participants positioning and expectations, thereby providing context for the knowledge that was produced.

Each scenario was a work of fiction which resulted from the meeting of participants' own skills and a speculative brief. The workshop's staging, in this way, took some participants out of their comfort zones. Those from a design background described the GNSS technology as "unfamiliar", "abstract" and "hard to relate to" because "we're not thinking about it every day". From the other side, while most designers were familiar with the workshop process from their own practice, one participant from an engineering background stated:

> "It's quite tough coming from a pretty rigid engineering background and working in a job where it's not particularly creative, to let that go and do this kind of speculative design thing."

Others picked up this theme, suggesting that many of their colleagues, especially the older ones, were quite set in their ways and "if you put a load of craft stuff in front of them and asked them to design stuff then they just wouldn't have any idea."

Here, "craft stuff" refers to coloured paper, post-its, scissors, glue and other stationary which the participants were given to make an artefact for their proposed future world.

From these quotes, we can see that both main participant groups found aspects of the workshops' staging variously familiar and uncomfortable. In developing their scenarios, they experienced limitations and moments of friction. From this collision of approaches, a sense of authorship, metaphor and world building began to emerge.

5.3.4.2 GNSS and Humanity

In each project, GNSS and humanity intersected in conflicting and complementary ways. Variously, humans were; an environmental danger to be controlled; something incidental, kept to one side as satellites pursued their own agendas; the object of judgment; or as actors which worked to establish alternative networks by hacking or bypassing satellite systems. As described in the notes on each project, these relationships can be understood as negotiations of agency within wider networks that include both human and infrastructural elements. The facilitation of these exchanges and negotiations of agency consistently came through shared conceptual bridges. These bridges are metaphors that allowed satellite and human interaction to be understood and the texture of those interactions to be felt.

5.3.4.3 Conceptual Bridges to Satellite Activity

To provide metaphors for how humans and satellites might interact in the future, and thereby cast light on existing formations and practices, the participants drew on a number of existing realms, concepts and practices. These were: The earth; Mapping; and Animal life. Much of the analysis up to this point has centered on the existence of negotiation of agency between human and infrastructural realms. The concepts described here offer routes through which to understand the metaphors around that negotiation of agency. These bridges provide the sites and processes through which the agential texture of GNSS is understood.

Earth

Earth was frequently posited as a shared field of operation, something which both satellites and humans had a stake in. While the human attachment to earth is obvious, several reasons for GNSS systems to be concerned with the planet's health were proposed. For the Group 1 (time-o-poly), Group 5 (earth guardians), and Group 2 (satellite

reproduction), the earth represented a site of resources which the satellite systems needed in order to sustain themselves and ultimately thrive. Group 4 proposed that the satellites continued to follow their initial programming, looking after the earth to make it productive for farming. Group 8, who proposed using mapping as a way of controlling movements on earth, argued that the satellites "are not evil, they're nice" and therefore worked to look after the earth. It is also worth noting that three groups discussed the possibility of having the satellites "look outward at space" or the moon, before deciding that, in fact they would concentrate on earth. In the end, no group, proposed that the satellites would be unconcerned with earth. Earth, therefore, acted as a shared field of operations and an overlapping area of concern for both satellites and humans. It was a site that allowed them to interact, bridging their interests and activities.

Mapping

The practice of mapping provided another bridge between humans and satellites. In Group 8's project, where satellites work as environmentalists, they use mapping to create different territories which are either attractive or unattractive to humans. Meanwhile, both plants and animals are given their own territories in which to recover from human activity. In Group 6's 'silverheads' example, blanket GNSS coverage leads to a blanket recording and mapping of peoples' movements. In these cases, therefore, the practice of making maps and navigating in response to them provides a powerful conceptual bridge and shared field of operation for both satellites and humans.

Animal Metaphors

Animal metaphors also worked to provide rich common ground between humans and satellites both through behaviour and modes of organisation. In the engineers' workshop, Group 2 suggested that satellites "would become their own species like a flock of birds" and develop complex mating rituals which they would perform in space. Two projects from the developmental workshop also offered animal-inspired or facilitated networks as alternatives to GNSS. In one, people were implanted with a magnetic crystal which

would give them a pigeon-like sense of direction, allowing them to navigate without the aid of satellites. In the other, bees provided an alternative network to distribute GNSS signals. While animals (in which I include birds and insects) are working to different ends here, what is relevant is that they provide a means through which to explore radically different futures which contain different behaviours and means of organisation. In this way, animals provide a powerful conceptual bridge through which to explore radically 'othered' intelligences.

5.3.4.4 Key Themes in a Stack of Overlapping Concerns

Through these conceptual bridges, a shared site of interaction and agency between humans and satellites emerges. The site is complex and dynamic with a broad swathe of combinations between the two. This is the site through which we can explore infrastructural texture both in terms of ontology and practice. I propose understanding it as an assemblage or stack [11] which gives rise to the actions that take place in the participants' scenarios. This stack, a meeting of GNSS and human positions, is manifested though these textural themes, each of which represents an example of intra-action [2] between the future GNSS networks and the humans which are left to interact with it.

The points described here fit into four meta-themes: Control and resistance; Benign power; A persistent tool; Learned behaviour. I describe each of them in detail below.

Control and Resistance

This first area of concern manifests in different ways in different projects, but is consistently themed around the drive from the infrastructures' side for control and resistance to that control, typically from the human side. We see this dynamic perhaps most clearly in Group 6's 'silverheads' project in which, to "enforce the law", satellites track everyone's movements and share them with the world. In response, an "underground movement" has emerged in response with people who want to see a "surveillance free society" and cover their heads with foil and their phones with concrete as a "first step" to

avoiding tracking. A similar relationship emerges in Group 3's project, themed around architectural forms. Here, the shape of the building is used to "collect the signal" or make it "bounce to nowhere" depending on what people want to achieve. The aim is not to block all signals, but to have more control at ground level in how they are received.

The power of GNSS to control life at ground level is also felt through human dependency on GNSS orientation. Participants acknowledged this process already exists in our time and proposed that "in 2040 we are so dependent on it that we can't orient ourselves any more without any help." In the developmental brief, in the face of having this service taken away, participants proposed hacking it and distributing it through other means (bee networks) or using an alternative system that would allow humans to navigate using the earth's magnetic field.

A connected way of resisting powerful satellite system is through "awareness". One participant in the designers' workshop proposed that people should become aware of how GNSS works and "construct [their] own system" in response. In addition to offering alternatives to the GNSS system, such a shift will, they said, allow people to "come up with other potential applications."

Benign Power

The power of GNSS in the future was not limited to the kind of dystopian scenarios described above. Three groups also proposed that GNSS would work to protect life on earth, working as a "guardian". While such behaviour was understood as a means of self-protection, preserving resources which are important to satellites' continued survival, at the same time, satellites were motivated by altruism. One group said that "they're nice" and worked towards a "greater good". Another group described satellites as having "a caring feeling towards the earth and they are looking after it unlike the humans that were there before them." Indeed, the guardianship offered by the satellites was typically done in a way that circumvented humans, who were seen as a destructive force. At best, while humans and satellites "kind of benefit from each other, they'd rather co-exist

than collaborate". In this way, the satellite system can be understood something like an ambient helper or guide. This understanding can be read as an elucidation of the support GNSS infrastructure provides to existing tasks and practices such as navigation.

One of these groups described a desire to avoid "a dystopian scenario where one [satellites] fights against the other [humans]." In this way, these scenarios mark a shift from those themed around control and resistance. However, these are not straightforward utopias either. In these scenarios, the dystopian element in the system is human action on the planet. The satellites choose to work against destructive human actions by corralling humans into certain areas or leading the cleanup after humans have destroyed themselves. In these cases, therefore, we may wonder about the relative positionings of satellite and human and what effect this may have on ideas of the 'user' as protagonist. This theme is picked up again in the discussion chapter.

A Persistent Tool

This third area of concern is strongly present in the group who focussed on agricultural production. This group proposed that the original function of GNSS still held true, albeit in an expanded form. They proposed that GNSS continued to support human activities on earth through its ability to add "perspective," supporting a stack of artificial intelligence agents in the collection of detailed information around yield and soil composition. Such a system will ultimately be led by "a few humans operating the machines" on earth. Here, therefore, the idea of GNSS as a tool within a "hierarchy" persists. The tool is motivated to support human needs and follow human instructions. Despite the ability of GNSS to identify its own areas of concern in the brief, it remains a tool and the human remains a user motivated to engage with a technical infrastructure to perform a task and solve a given problem.

The 'tourist' group from the first workshop also followed this model. They proposed GNSS systems that were splintered along national lines and which competed for users according to their needs. In this way, a tourist could choose different travel packages

depending on how they wanted to use GNSS. Such a scenario also closely matches our present uses of the technology. The tourists would use the service primarily for navigation, with some added social networking functionality. In this project therefore, the idea of GNSS as a human-directed tool was again persistent.

Learned Behaviour

In the final area of concern, satellites also drew on human behaviour. However, rather than following human directions, they imitated human actions. This was most strongly felt in Group 1's scenario in which different satellite systems competed to accumulate resources, with the ultimate aim of ''taking over the world." The participants behind this study described it as a "kind of hyper-capitalist dystopia" where satellite systems:

> "need to do this to satisfy its goal which is optimised away from just being able to function as a system to ensure that it has neutralised all threats in its environment."

Reflecting on their scenario, this group acknowledged the human roots of their themes, stating that: "we went for typical human desire which is to make lots of money and defraud the stock exchange." The same participant also drew parallels with the Group 2's project in their workshop in which satellites coupled up and formed monogamous partnerships:

> "So, both scenarios are rooted in a now kind of human obsession and a way of thinking about each other and the world."

The use of human motivations to understand infrastructural ones represents a kind of anthromorphisation. While these two are strong examples, the point is relevant to all the projects. Whether they seek to address the wicked problem of climate change and environmental destruction, create a blanket field of surveillance or work to increase crop yields, each scenario is rooted in human fears and desires.

5.3.4.5 Summary

From this last point about anthropomorphism we can say that, although the workshops did not always produce a radical shift away from user, or human-driven understandings of infrastructure, they were able to give perspective on infrastructural texture. These textures concern how the participants saw themselves and their practices in relation to the current and possible actions of the infrastructure. One dynamic that emerged strongly was the idea of control and resistance. This is similar to the surveillance and privacy dynamic from the walking workshops. However, with this more ontological framing, the theme is understood more broadly. How can humans maintain agency in the face of a powerful and independent infrastructural agency? Other groups saw the human-infrastructure relationship as less combative and, instead argued for an understandings of infrastructure as a 'benign power' and 'persistent tool'. This is similar to the relationship we typically understand users as having with infrastructure currently and suggested by Star and Ruhleder [7]; that it will support our practices in a more transparent and odourless way.

Beyond these two strong dynamics, the question of infrastructural agency and motivation was more slippery, with the majority of groups in the engineers' workshop arguing that the satellites would be motivated primarily by their own survival. For Group 2 this was understood in animalistic terms (through procreation), for Group 1 it was understood in more human terms (through the accumulation of resources). In all cases, a focus on the of combinations that emerge when we consider the meeting of human and infrastructural agencies can be taken of evidence that the workshop was able to address the second research question. An analysis of how much and and in what ways the method was able to shift understandings about the centrality of the user and the presence of more-than-human networks follows in the discussion chapter.

5.4 Conclusion

In this chapter I laid out my findings from the two methods used in this project. The data from the walking workshops was understood through three stages: Alienation; Environment and Dynamics. Within the dynamics stage particular relationships between user and infrastructure were negotiated by participants, providing a sense of infrastructural texture.

The second study was more conceptually open and, as such, a number of metaphoric realms emerged through which to re-think the relationship between user and infrastructure. These were: the earth as a site of shared interest between humans and satellites; mapping as a practice that can facilitate power relations; and animal metaphors used to conceptualise non-human concerns. Within these realms, several dynamics emerged to understand how an infrastructure which demonstrated more agency would interact with humans and the world at large. These were: Control over human populations and resistance; Satellites as a benign power or guardian angel; GNSS as a tool which continues to serve human goals; and Satellites which exhibit behaviour learned from human practices. In these cases, the method allowed me to consider the themes around human and infrastructural agency, their points of contact and their negotiation. This exploration of intra-action is understood as a way of diagnostically probing both existing sociotechnical practices and what they mean for ontological shifts around more-than-human networks.

In the discussion chapter I go on to consider the theoretical and practical implications of this work. I describe how successfully these findings address my research questions, consider the kinds of knowledge which can be gained from applying poetic techniques and argue for the contribution they can make to both HCI and STS.

Before that I use the following chapter to describe the artistic projects that emerged from this work. These can be understood as my own response to the research questions and the desire to shift understandings away from existing sociotechnical practices.

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Chapter 6

Artistic Outputs

As I worked on this PhD I continued to develop my artistic practice. During this period, much of my work began to revolve around the questions I was investigating regarding GNSS. As part of this process, I conducted several projects that used techniques similar to the walking method described in previous chapters but foregrounding artistic outcomes. These examples strongly emphasise the poetics of satellites and their potential to offer what I characterise as new mythologies for GNSS. In so doing, they offer an inversion of GNSS infrastructure, drawing attention to the infrastructure and foregrounding narrative and metaphor in the creation of something new and other-worldly. This alternative mythology for GNSS is therefore the goal of the work described in this chapter. This is somewhat different from the stated research goals, which work to elicit of a diagnosis of the texture of existing sociotechnical practices or infrastructural ontologies. The projects described in this chapter can be understood as my own response to the kind of prompts offered in the workshops in which I ask participants to reflect strongly on their practices and work to shift their understandings.

The key project described here, *GPS Tarot*, offers an infrastructural inversion of GNSS through the development of an alternative poetic mythology. As with the other work described in this thesis, it foregrounds the infrastructure that supports location

services, but does it through the use of extended metaphor. Historically, humans have used the stars both as navigation aids and as a source of storytelling and divination. *GPS Tarot* uses the position of overhead GNSS satellites to draw up a chart of tarot cards that is then used to give people individual readings. GNSS satellites are frequently used to allow us to orient ourselves in space, their re-framing in *GPS Tarot* also provides a way for us to orient ourselves in the events, actions, affects and emotions that make up our lives.

Before offering a detailed discussion of *GPS Tarot*, I describe a workshop-based project that took place at an artists' residency in Delphi, Greece. The project is a walking workshop in the style described in this thesis, but worked to engage with the symbolism of the infrastructure rather than by tracking its operation. The workshop took place around the ancient Temple of Athena and made me consider mythology as a mode of storytelling which could be made relevant to satellites. *GPS Tarot* which was developed over the course of the Sound Development City artistic expedition took this interest in mythology further.

6.1 Made of Walking

The desire to create a new mythology for GNSS was first kindled by my early speculative design experiments in Fengersfors, Sweden. One participant's drawn response showed diverse scenes including a priesthood invoking GNSS signals and people sheltering from them. This made me want to explore different ways in which one could interact with the presence and materiality of GNSS signals, especially in more symbolic ways. This idea was given a further push by participant responses to the walking experiments around the Barbican. Some participants placed emphasis on our existence in a hidden electromagnetic realm, composed of different types and densities of signal. Awareness of this realm, it seemed to me, offered the potential to tell new stories around the operation of GNSS.

My first attempt at re-narrativising GNSS came at the Made of Walking residency in Delphi, Greece in July 2016. I had been accepted on the residency through a proposal to conduct a workshop of the same type as those in London and Manchester; walking with awareness of GNSS satellites. Each project on the residency involved a walk in or around the town or archaeological site of Delphi, historically the seat of the ancient Greek oracle. My own walk took place around the Tholos monument, part of the temple of Athena dating from between 380 and 370 BC. The Tholos is one of the most striking parts of the Delphi site and its circular form put me in mind of satellite orbits. The walk took the same form as the others described in this thesis, with a brief technical introduction followed by free walking at the site using the *GPS Test* app. The participants then did their own written and drawn response before having a group discussion.

I chose not to include this workshop with the data from the others because of the radical differences in site and staging. In technical terms, at the Tholos, there were no tall buildings in place to disrupt the functionality of GNSS, the site was also not necessarily one where participants could imagine performing their usual sociotechnical practices. In short, the Tholos was not an everyday space, but a dramatic ancient site, full of poetic resonance with (ancient) time and myth. By walking around the site with attention to the presence of satellites, I hoped this experiment would give GNSS a very different framing, as something outside our own time and history. In this way, it achieved a sense of infrastructural inversion, not by engineering moments of breakdown in the smooth operation of the system, but rather, in combination with the site, by leveraging the infrastructure to create a radically different set of poetic and metaphorical resonances. Bowker argues that blackboxing means that the development of infrastructure gains an aura of inevitability, as if their development could not have taken any other course [1]. The re-framing of GNSS infrastructure in mythological terms offers a radical alternative account of the infrastructure's, emergence, symbolism and use.

The drawings which participants made in response to the walk concentrated on the dimensions of the Tholos itself, with the majority placing a circle at the heart of the

Figure 6.1: Participants walk around the Tholos at the Temple of Athena in Delphi, Greece.

image. From there, the presence of satellites were noted in waves or azimuth angles. Two images drew directly from the site of the walk, including ancient or mythological figures. The one included below (figure 6.2) appears to be a constellation composed of star or satellite positions.

In this and other images, the presence of the site is extremely strong. I would go as far as saying that the work became about filtering the site through an idea of satellites rather than filtering potential satellite mythologies through the site. Building on the strength of the site in forming participant responses, the experience encouraged me to continue to search for new sites and framings. I would use these to ground satellites in acts of myth-making and use mythology to shift understandings of GNSS.

Figure 6.2: Participant drawing from workshop at Delphi showing a mythological figure above the Tholos, perhaps composed of the different constellation points of satellites.

6.2 GPS Tarot

I took the experiences at Delphi with me to another residency in September 2016. My proposal here was expressly to work towards "a new mythology for GNSS". This residency, Sound Development City, took place between Madrid and Casablanca with a week in each city and time allocated for travel between the two. I conducted similar walking exercises in both cities. Given the freedom to experiment, I included several new workshop tasks. I wanted to build empathy with satellites as objects so I led participants through a guided movement exercise where I had them close their eyes and imagine they were in space. The exercise was accompanied with a sonification of the

surrounding electromagnetic field using a Detektor device developed by artists Martin Howse and Shintaro Miyazaki [2]. In the writing and drawing section of the workshop I asked participants to draw a self-portrait of themselves as a satellite. Developed in this way, the workshop became a stand-alone project, where the act of taking people outside their usual sociotechnical practices began to speak to a different type of presence and existence, one more sympathetic to other elements in a more broadly understood more-than-human network.

6.2.1 Development

As part of the Sound Development City project, local fixers were employed to help artists access local networks. To research how I might approach a new mythology for GNSS, I had asked to be put in touch with astrologers, astrophysicists and psychics in both cities. My intention was to hold conversations with these people about GNSS and how they could imagine the infrastructure fitting into the world-views which had emerged from developing their expertise.

In Madrid, it was surprisingly difficult to track down astrologers and psychics to talk with. I did, however, have a very useful interview with Judith Palacios, an astrophysicist. She was particularly interested in parts of the electromagnetic spectrum which could be seen or felt by animals such as scarab beetles and birds. The conversation moved on to talk about what sense experiences a satellite might have whilst in orbit. While the idea of satellite sensing was difficult to pin down, she emphasised that satellites do not exist in a vacuum, but are rather "like fish in a sea of electromagnetism". This sea has its own currents, made of radio waves and solar weather, which can nudge and buffet satellites off course. Despite our impression of space as a still and calm place, outside our atmosphere it is turbulent and often violent. This knowledge inspired me to develop the additional workshop tasks described above and to incorporate the Detektor unit further into my project, later going on to use it as a sonic backdrop for GPS tarot readings.

With the limited success in talking to astrologers and psychics I decided to take matters into my own hands and buy a deck of tarot cards. I wanted to use them somehow in my project and received some advice from Raisa Maudit, a Madrid-based artist. She uses chaos magic throughout her work, and, through a conversation with her, I decided that, rather than create satellite-themed tarot cards or card equivalents, it would be much more profitable to create a new system for reading cards. This would allow the potential for new narratives to emerge, both in terms of the macro-narrative around the use of GNSS and through the micro-narratives involved in the montage of individual cards during a reading. Formed this way, a chart or reading system built from satellite positions can offer rich outcomes both for the positioning of the project and in the resonance of individual readings.

I spent the journey from Madrid to Casablanca getting to know the major arcana of my deck. I had chosen the Marseille deck, one of the oldest, as compiled by surrealist film director Alejandro Jodorowsky and Phillipe Camoin. I was familiar with Jodorowsky's work and trusted his sense of aesthetics and drama. This deck and Jodorowsky's approach to tarot is also extensively described and documented [3], making it easier to learn quickly from scratch. I continued to study the cards after arriving in Casablanca where I also sought out astrologers and psychics to speak with about my approach. After an unsuccessful attempt to approach fortune tellers around the Sidi Bou Abderrahmane shrine, I got an appointment with a card reader in an upscale Casablanca city centre neighbourhood. The exchange turned out to be more of a reading for myself than a conversation about satellites, but he told me that I would be successful in my card-reading practice and that I was ready to start taking on clients. Encouraged by this, I began giving *GPS Tarot* readings in time for the closing event of the residency.

The readings took place on the roof of a building with a clear view of the sky. I used *GPS Test* to establish the positions of satellites overhead and laid out cards in a corresponding pattern. To read the resulting chart, I had decided, with input from fellow artist resident, Youmna Saba, to use palm-reading as a model. I read two lines.

The first runs vertically down the left side of the chart. This 'life line' refers to actions and events. The second line runs horizontally from the right of the chart. This is the 'emotional' line (see figure 6.3) This approach is flexible enough to allow each reading to be tailored to someone's hand, with slightly different lines being read according to the paths these lines take on the palm. The readings are accompanied by the harsh, static-y sounds of the Detektor, amplified through a portable speaker. This serves to give the readings a more dramatic staging and establish some kind of empathy with the satellites overhead in their electromagnetic sea. Each reading typically lasts around 20 minutes.

6.2.2 Orientation

Since September 2016, *GPS Tarot* has been performed for friends and colleagues and as part of public-facing conferences and exhibitions. Over this time I have continued to study the cards, becoming more familiar with the meanings they can carry both individually and in different combinations. Throughout this practice I have come to resist describing the readings as fortune telling; arguing that, rather than telling the future, they are telling the present. Readings are understood as interpretive and open-ended, not providing accurate information which the respondent should act on. This move subverts GNSS's traditional drive for ever greater accuracy. There are practical as well as conceptual reasons for this. GNSS satellites move in relatively fast mid-earth orbits and, due to shifting satellite positions, a reading made even one hour later will yield dramatically different results. As such, the practice provides space for participants to reflect on the present moment and its transience. It echoes the storytelling and divination potential people have long ascribed to the stars, giving people a sense of what external forces may be affecting them. It adapts this role to offer a new perspective on how GNSS satellites tell us stories about where we are on the earth's surface.

The comparison between satellites and stars serves to give this project a powerful "conceptual bridge" [4], a concept which greatly enhances the ability of speculative design projects to connect with an audience. The conceptual bridge ensures that the

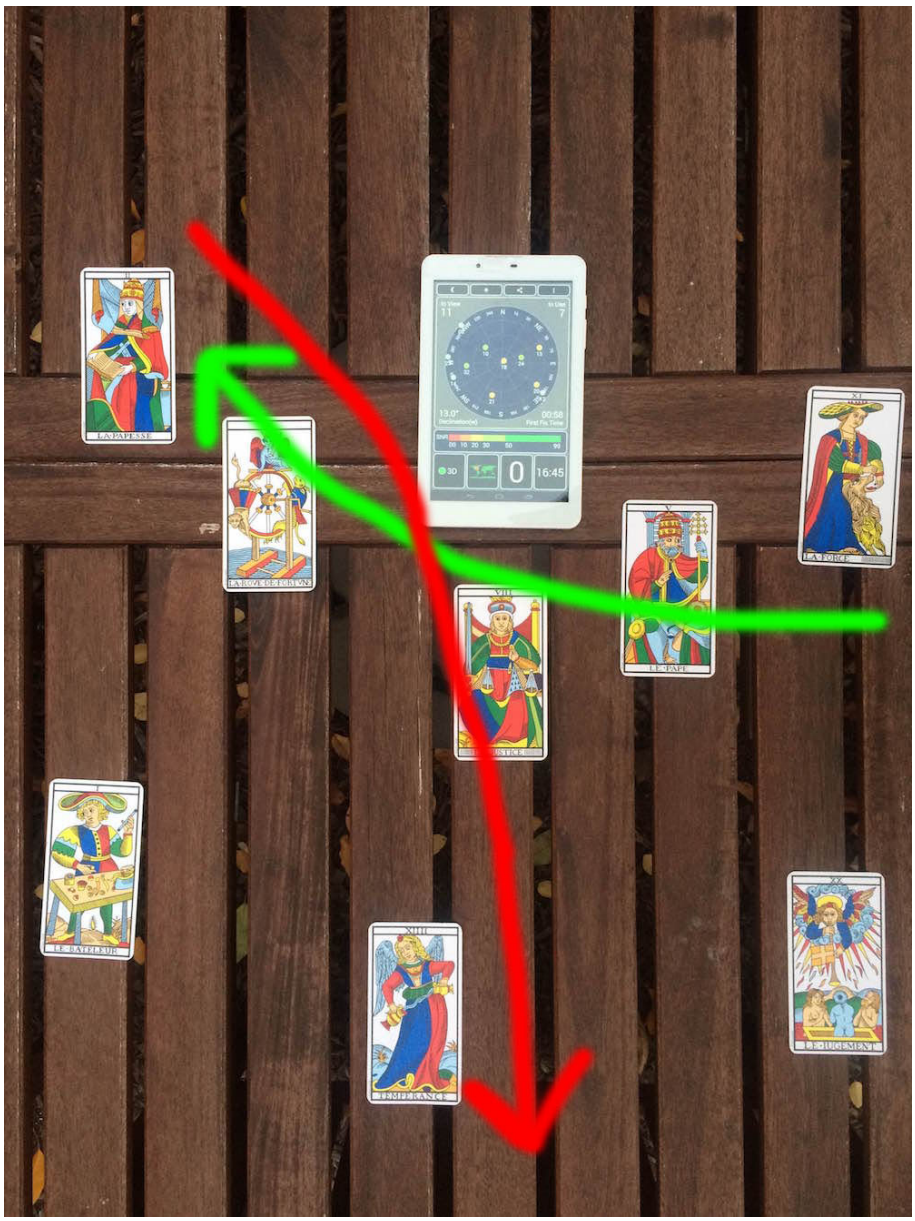

Figure 6.3: GPS Tarot reading showing cards and corresponding satellite positions on *GPS Test* running on a tablet. The red line shows the cards read in the 'life line', the green shows the cards read in the 'emotional' line.

project is not too distinct from familiar experiences. This is important for providing the suspension of disbelief which speculative design projects often work towards, proposing products and services which derive power through their credibility. For *GPS Tarot*, the comparison with the stars provides one important conceptual bridge, with the other being the use of tarot reading, an established and familiar divination practice.

6.3 Discussion

GPS Tarot represents an answer to prompts which I developed throughout the PhD process. It can be understood as my own speculative design project, developed in answer to a call to rethink our relationship to GNSS infrastructure. I have made no attempt to offer a formalised evaluation of the project, nor do I necessarily think that would be appropriate. The project is designed to create space for reflection on our relationship with GNSS infrastructure, but, at the same time, it creates space for participants to reflect on their own lives. In this way, GNSS infrastructure becomes active in a new way, creating new meanings by posing new questions. The project proposes an alternate reality where we can gain guidance and inspiration from satellites via a poetic and figurative process, one which asks questions but does not seek answerability.

Informally, the responses to *GPS Tarot* have been positive. I have performed around two hundred readings to date both in person and over text message. People report surprise at the presence of the satellites as they are made visible using *GPS Test*, and a general interest in the project as it relates to the functioning of the infrastructure. It has been frequently noted that the satellites change position during the reading, which leads to a discussion about their orbital pattern and speed. Much of the discussion emergent from the readings focusses on the content of the cards and their significance for the participant. This leads me to believe that the poetics at play in *GPS Tarot* are effective at creating an alternative symbolic context for the infrastructure.

In this way, the work can be understood as achieving infrastructural inversion through a number of routes. Firstly, it foregrounds the infrastructure through the use of *GPS Test*. This route is similar to the one taken in the walking workshops and, to some extent, during the Made of Walking residency. The software visualises the presence of satellites overhead, thereby shifting attention from a location fix to the infrastructure that provides that location fix.

Secondly, it offers an alternative framing of the GNSS network. Rather than being

something developed initially by the US military to help locate and direct missiles, then used later for civilian navigation purposes, GPS satellites specifically (and GNSS satellites at large) are re-framed as something other-worldly that offers signposts to different kinds of knowledge, rooted in the occult. The walk at Delphi also offers a different temporal origin for GNSS; rather than a 20th Century technology, the presence of GNSS satellites is understood as something consistent with ancient monuments and the divinatory power of the Delphic oracle. This shift points to a form of infrastructural inversion identified by Bowker [1] in which an alternative accounts can disrupt the narrative of development around an infrastructure and, thereby, help us imagine alternative forms it may have taken. For *GPS Tarot*, the fact that much of the discussion during readings focussed on the significance of the cards can be taken as evidence for the success of this re-framing in providing an alternative way to engage with the GNSS system.

GPS Tarot also shifts understandings by suggesting that it is possible to gain insight to our lives through a symbolic understanding infrastructural actions and agencies. The project still emphasises the user, but offers the user a defamiliarised and expanded experience which is achieved in collaboration with the tarot reader and the positionality of the satellites. This experience offers the possibility of more-than-human networks, by suggesting that GNSS satellites, rather than being simply man-made, are part of something that exceeds human temporality and can, in turn, provide new forms of knowing.

6.3.1 Outcomes

The project has enjoyed some success as an installation / performance, with readings having taken place at events in Viechtach, Germany; FACT gallery, Liverpool; the DIS conference in Edinburgh [5] and the Electromagnetic Field festival. The project also has a more mobile existence via a series of *GPS Tarot* business cards distributed at events and via friends and colleagues. The card has a phone number and instructions to get in contact via SMS or *WhatsApp*. On receiving a question or a request for a general reading, I text back, creating a chart according to satellite positions above my location

and reading an action and emotional line. This means of disseminating the work has been quite successful and to date I have performed around 100 readings over text message.

A disadvantage of the text message model is that I do not share the same space with the participant. This makes the reading less personal and shifts the significance of using overhead satellites. The satellite positions during a reading will be local to me as the reader and not to the person being read. I make this clear when I text back, but some of the affective power of the work is certainly lost. On balance, however, the business card / text message model is beneficial to the project in that it allows the it to have a broader and more complex dissemination. The cards are not mass-distributed, but rather passed from hand to hand, creating a network of trust more in keeping with the personal emotional work involved in giving a tarot reading. An analysis of the *GPS Tarot* business card as a means of distributing work has also since been published [6].

6.4 Conclusion

These artistic projects represent another outcome of the PhD work, one which is valuable both on its own terms and as a contribution to the wider research project. In Salter's understanding of how art can intersect with STS [7], this work can be seen in part as public-facing science communication work. The two projects described here also contain a pedagogic quality through the ways they use *GPS Test* to draw attention to GNSS infrastructure and explain its operation.

Within the wider research project, the work also represents a form of infrastructural inversion, but one less concerned with breakdown and more concerned with alternative histories [1, 8]. Through their transparency, it is often difficult to imagine that infrastructures could have developed any other way. The work described in this chapter gives them a different history, symbolism and resonance.

In this way, the artistic work carried out here can be understood as my own creative

response to the broader research project. The bulk of the work described in the thesis elicits participant responses to create a shift in attention around GNSS infrastructure. *GPS Tarot* represents my own answer to the shift in attention proposed by the speculative design method.

GPS Tarot is still an active part of my artistic practice and I continue to give readings at galleries and festivals.

Figure 6.4: GPS Tarot business card for readings given over SMS or *Whatsapp*.

Figure 6.5: GPS Tarot reading being given at the Geodatisches Observatorium, Wetzell, Germany.

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Chapter 7

Discussion

In this chapter I discuss my research findings. I begin by describing the use of poetic techniques. These techniques create new prompts and situations that encourage re-imagining an existing infrastructure through a new set of framings. These re-framings allow the development of new metaphors through which to understand the "texture" [1] of this infrastructure. Texture here refers to the way in which we can understand an infrastructure by describing its actions. The 'poetry' of these methods initially comes through the way an infrastructure is re-framed in the research staging and then through metaphor-rich responses given by participants in response to this staging. I argue in this chapter that while poetic methods can also feed into individual art practice, they will be most transferrable for researchers in STS and HCI when understood as a modular tool to be used within a wider research framework. This tool is guided by a keen attention on the power of metaphor and symbol in re-framing infrastructures and examining sociotechnical practices. In considering what kinds of knowledge poetic methods can generate, I consider their potential for research, pedagogy and art production.

I go on to discuss the application of these techniques through the kinds of metaphor that they created over the course of this PhD project, considering how the two sets of research workshops and artistic works engage with my research questions. The questions

address how poetics and metaphor can engage with both the experienced texture of blackboxed infrastructures and ontological questions around the centrality of the user and more-than-human networks. I outline how the questions were addressed and what remains unclear.

I then argue that this approach offers something new to the existing canon of research techniques in both HCI and STS. The strength of such techniques lies in their ability to access obscure and hidden questions, whether that obscuration be the result of a process of blackboxing in practical terms (such as information about GNSS functionality not being readily available through existing interfaces) or through those questions being more philosophically obscure (such as ideas about the intra-action across more-than-human networks). I also consider where these techniques can contribute to ongoing debates in HCI. I conclude the chapter (and the thesis) by offering some suggestions for how these techniques could be further refined and by describing some possible directions for future work.

7.1 What Kinds of Knowledge do Poetic Methods Produce?

Poetic methods sit at the overlap of art and research practices. They seek to create new knowledge at the same time as creating immersive experiences that ask people to re-consider their relationships to technologies, infrastructures and their sociotechnical practices. These two drives are not distinct. The creation of an immersive or affective situation which asks participants to critique their usual practices is employed as a research technique for catalysing participant reflection and, thereby, creating thicker, richer and more complex understandings. The outcomes of this process are understood in both art and research contexts.

As described in the introduction to this thesis, artistic work has fed into STS research

for many years, not least through Latour's argument for art and curatorial practices as "thought experiments" [2] which are largely free from academic disciplinary conventions and boundaries. Salter, Burri and Dumit offer four ways that art practices can contribute to STS: As a means to explore the production of science through aesthetic experiences; As a way to add to methodological techniques; As an extension of public-facing science communication; and in a radical role of questioning and critiquing the political formations of existing practices [3] (p. 140).

For clarity, I include a table of how poetic methods may be used in relation to three areas that draw from Salter et al's proposal for art practice to feed into methodological techniques (research), question and critique existing political formations (pedagogy) and produce aesthetic experiences (artistic work). I emphasise that there is great potential for overlap in these areas. Following the table I explore each aspect in more detail:

Research	Pedagogy	Artistic Work
In framing participant studies in a way that emphasises hidden or obscure actants and using this to catalyse reflection on sociotechnical practices and ontologies.	Again, in framing participant studies in a way that emphasises hidden or obscure actants, using this to catalyse reflection on sociotechnical practices and ontologies.	Building on participant workshops to create work that offers deeper and more developed poetics. In turn, this can create further work that critiques and re-frames hidden and obscure actants.
In reading participant responses with a focus on the interpretation of metaphor to describe textures.	In using this re-framing to emphasise the generation of new perspectives for participants during the workshop.	

Table 7-A: Uses of poetic methods in different realms.

7.1.1 Research

Here I would like to emphasise what poetic methods can offer to other research approaches, particularly through their use in framing and re-framing participant-facing studies.

Poetic methods have the ability to foreground elements of assemblages which are typically tacit or hidden. They do this through acts of re-framing, critiquing usual practices or offering alternatives. In the work described here, this is done both through the material explorations of the walking method and the metaphor-driven work of the design workshops. The aim here is to re-frame existing sociotechnical practices to make what has been naturalised seem new and unusual, and then to leverage that re-framing to explore infrastructural textures through the use of methods centered on symbol and metaphor.

In the walking workshop, the framing of the experiment offered participants a different kind of structure against which to orient their practices. While it was my aim to challenge the blackboxing of infrastructure, I create, in its place, something that could perhaps be called a greybox. This box is ambiguous, unfixed and uncertain, but through this uncertainly, new understandings are allowed to emerge. One of these may be a new appreciation for the complexity of the infrastructure. In the words of one participant:

> "I think for me theres something about being reminded just how complex a device I was holding, which is something I dont normally consider in my day-to-day action."

The role of the researcher is, in part, to create a set of research conditions in which participants are encouraged to reflect on their practices in greater detail. As a research tool, the *GPS Test* software acted outside participants' usual practices, drawing attention to infrastructural elements that are causally influential, but not immediately obvious. Traditionally, within design inscriptions around ubiquitous computing, attention has been taken away from the tool and directed towards the task at hand (e.g. [4–6]). However, such an approach limits understandings by concealing the explanatory power provided by the complex infrastructural elements that make up the tool.

Throughout the work described here, metaphor plays a strong role. It provides a way to address tacit and hidden elements of the sociomaterial assemblage through art

practice, study framing and participant responses. The results can be powerful, re-framing technical infrastructures and allowing participants to approach them through new lenses. It should, however, be noted that the metaphors suggested by participants may not always be materially accurate. This is seen strongly in the drawing of satellites' sight lines coming down from space and repeated references to satellites as "eyes" or "watchers". As noted previously, this is technically incorrect. The GNSS satellites themselves are passive and do not 'see' or receive information on devices' locations. The recording of this information comes further up the data chain, most likely in the devices operating system or in apps that collect location information. In the design workshops, technical details in participant scenarios were often sketchy with GNSS infrastructures understood as, variously, able to direct humans to certain areas of the planet, actively intervene in human social life and reproduce in space.

It should be noted, therefore, that some leeway is needed in understanding these metaphors and how they describe the infrastructure. The metaphors that result from poetic methods may not describe literally how infrastructures act, but rather how they are felt to act. This is consistent with an idea of texture concerning how the actions and rhythms of an infrastructure are understood through their use [1]. This focus does, however, raise questions around the continuing centrality of the user or, indeed, the human element in more-than-human networks. Although strong attention is drawn to the action and agency of non-human, infrastructural elements, that attention is still measured through human metaphors and experience.

The work, therefore, does not negate the figure of the human or the user, but rather re-focuses it as one part within many. This means that, rather than offering an account of infrastructural agency removed from the human, poetic methods offer a way of de-focussing the human user as a centre of meaning. At the same time it is worth noting that the (human) participant studies used here ultimately seek to draw on participants' thoughts and experiences rather than the experiences of an infrastructure. As I write these words, I am aware that 'the experiences of an infrastructure' is an onto-

logically problematic proposition, open to accusations of reductive anthropomorphism. To foreground infrastructural agency more strongly, I argue below that artistic practice, through its resistance to reductivity, may well be a more appropriate forum than participant studies to carry out this work.

7.1.2 Pedagogy

Throughout the research process, one of my aims has been that this work can provide a pedagogic aspect as well as a diagnostic research role. I understand pedagogy here in very broad terms, as something which causes reflection and self-critique rather than in terms of skill-building or instruction. In this I have followed Matt Ratto's critical making approach which suggests collective design workshops based around material (or in my case, metaphorical and ontological) production as a means of thinking through how technologies are used and what they signify. The distinction between material and ontological production is important because, in material or technical terms, some of the knowledge generated by participants was incorrect. As described above, the heavy use of metaphor led to understandings of how an infrastructures agency was felt to act rather than how it acts under a technical description. The focus, therefore, was on a form of ontological pedagogy in which participants are asked where they understand the boundaries between themselves, their technical practices and infrastructures end, overlap and produce new forms of relations. In Baradian terms, this ontological work asks participants to identify and critique "agential cuts" [7] between themselves and other parts of sociomaterial assemblages.

Following the design workshops, I asked participants to fill out a brief, informal questionnaire to report back on how they had found the workshops, if they had learned anything new and if it had made them re-think their existing practices. I asked them to rate how engaging and challenging the workshop was, and if it had "made them think" using a Likert scale of 1 to 10 (where 1 is the least and 10 is the most). This method was used for speed and simplicity and participants were encouraged to write more

detailed optional feedback elsewhere on the questionnaire. Participants gave an average 'engagement' rating of 7.77, 'challenging' rating of 7.06 and a rating of 8.59 as to whether it had 'made them think'. In written feedback, participants reported: being surprised to learn certain technical details about the infrastructure (such as the use of atomic clocks); developing a stronger understanding of the infrastructure; feeling they had taken it for granted; and being more open to thinking about uses for the infrastructure besides navigation. There does, therefore, appear to have been a clear change in participants' knowledge of GNSS and understanding of its current and potential uses.

A similar deepening of knowledge and shift in perspective was also present in the walking workshops where, despite the lack of a separate questionnaire, participants reported being reminded of the presence of the infrastructure and, when reminded, being surprised about how they related to the presence of satellites. This shift in awareness was stated strongly by the participant who emphasised the "subversive" quality of "locating the satellite rather than locating yourself." The pedagogic aspect does not, therefore, necessarily involve conveying new information, but rather, using the re-framing of existing knowledge through infrastructural inversion to tease out what has become hidden or tacit. From these experiences, therefore, I note that poetic methods do indeed have the potential to work pedagogically, deepening knowledge and shifting participant perspectives. This may take place through an increased knowledge of technical details or a more ontological shift. In the words of one participant's questionnaire response: "I feel more positive about the future now. We wanted to draw an image of utopia for both species; satellites and humans. So maybe the future is bright after all?"

7.1.3 Artistic Work

The artistic outcomes of the project resonate with Salter et al's calls for work at the nexus of art and research to act "as a means to explore the production of science through aesthetic experiences and in a radical role of questioning and critiquing the political formations of existing practices" [3] (p. 140). For the first point, the production of

science is understood broadly, not so much in terms of formal research, but in terms of the operation of technology and the worlds it produces. This understanding allows it to dovetail with the second point, to question and critique political formations of existing practices. As described above, the walking and design workshops questioned existing practices directly. The artistic projects sought to establish a new, alternative mythology for GNSS infrastructure, offering a new way to conceptualise and interact with it. In this, they were dealing explicitly with questions around the ontology of GNSS and how it could be understood as a node in more-than-human networks.

The artistic work described here is more flexible than the research work, able to operate with fewer disciplinary constraints and produce more ambiguous outputs that need not be filtered through tight analysis or comparison with other studies. Rather, the work is able to propose radically different framings for GNSS infrastructure. For this reason, the artistic products of the work can be extremely powerful. They operate as a further outcome of the participatory workshops that form the bulk of this research, one that is highly specific to the sites and partner organisations that support them. While they are more difficult to quantify, they have a greater freedom to extend ontological speculations in a way that need not be tied to existing practices.

As such, it is difficult to propose a rulebook or set of standards through which to produce or evaluate this artistic work, since each manifestation will likely be different and specific to the project at hand. As it is performed, the work will likely produce unexpected outcomes, contexts and resonances. By way of informal evaluation, since the development of *GPS Tarot*, I have given hundreds of readings, both in person and over text message. While, for some, the project acts as a thought-provoking way to critique GNSS infrastructure, others find meaning in the tarot reading and the narratives it draws out concerning their lives. Others who are already familiar with tarot have commented on the unusual form of the readings and my approach to weaving stories from the cards. By these examples, I mean to argue that once a piece of artistic work is in the world the terms under which people approach it cannot be anticipated or

controlled. This is especially true in interactive work that requires a meeting of intent from artists and viewer/participant. The artistic work described here is concerned with staging encounters, but in a way that is looser than the research workshops, and less beholden to the creation of knowledge. In this way, although it starts from a desire to address the research area, art practice may become more concerned with the creation of an open-ended experience for the visitor.

7.2 Research Questions

Throughout this thesis, I have been using these methods to address the following questions:

1. How can poetics and metaphor be used as research methods for getting at the 'texture' of blackboxed infrastructures?

2. Does this way of shifting attention towards infrastructure:

    - Change understandings around the centrality of the user and user experience?

    - Change understandings about the nature of more-than-human networks?

To review my first research question, I describe the techniques I have used to re-frame blackboxed GNSS infrastructure. I discuss examples of how poetic methods were used to re-orient participants and invoke and understand participant responses which are rich in symbol and metaphor, thereby accessing the "texture" of the hidden infrastructure. To consider the second question, I review the kinds of ontological critique my research methods were able to invoke and how they can be read in the contexts of user-centeredness and more-than-human networks.

7.2.1 How can poetics and metaphor be used as research methods for getting at the 'texture' of blackboxed infrastructures?

In their diagnostic role, poetic methods can inspire reflection about sociotechnical practices and call attention to the textures of infrastructures that may not operate in plain sight. Symbolism and metaphor provide a powerful way of accessing these textures. For example, in the walking workshops, several participants drew attention to the idea of being watched through the operation of GNSS. Although the satellites were not literally watching them, the language and imagery used was around "eyes in the sky". This metaphor points to a series of concerns around the use of GNSS and location based services. Participants went on to discuss a privacy calculus through which they understand what is lost in terms of privacy and what is gained in terms of functionality when using these services. This discussion was able to take place because of the way in which the workshop drew attention to the satellites, reminding participants that "they're really up there." In addition to thinking about their own practices and positioning, participants also considered GNSS from other points of view. An example of this is the discussion of the importance of a GNSS-enabled phone for refugees who travelling across Europe. In this case, the initial framing of the workshop, and the power of re-framing an infrastructure to catalyse participant reflection led to a discussion of sociotechnical practices from several different viewpoints.

Another viewpoint came from a participant described the satellites as "blind researchers" seeing the "city as braille". This suggests a set of alternative senses for the infrastructure based around electromagnetic signals understood as the satellites' point of contact with the user and the city. It was also suggested that such signals could provide new ways of conceptualising infrastructure, allowing the construction of buildings designed for signal traffic.

As well as exploring sociotechnical practices, the symbolism of signals had a strong role in exploring the ontological texture of blackboxed GNSS infrastructures. In the

walking workshop, the idea of a hidden signal realm of overlapping and interfering electromagnetic communications provided a powerful ontological metaphor through which participants explored their own positioning in relation to GNSS. This came through speculation on how their own bodies were absorbing and reflecting the signals in this realm.

Later, in the speculative design workshop, poetic methods contributed to the exploration of the symbolic role of GNSS infrastructure through metaphors of: a guardian angel; an infrastructure that coerces us into types of behaviour; or a powerful extension of capitalist accumulation. These symbols can be understood as manifestations of textures, ways in which the infrastructure is understood through its effects, repeated until they form a more fixed idea of the role or positioning of the infrastructure. These symbols also have implications for understandings of the ontology of the infrastructure, particularly how it is understood in relation to the positioning of 'users' and / or 'humans'. As is discussed in the following sections, these symbols provide us with ways in which to understand the "agential cut" [7] through which emergent actors (infrastructure, human, practice) are contained and understood.

Poetic methods hold the potential to generate knowledge around a given theme via metaphors driven by re-framings of ontology and practice. They are able to do this through art as well as research practice. In their dual art / research role, they can offer what Benschop calls "enriched forms of knowing" [8] where research is approached with attention to different textures than those we are accustomed to. This form of reflection adds another meta-layer to knowledge production which can effectively follow Law's call for methods to hold things steady for a moment in a flux of indeterminacy [9] and Asdal and Moser's call for methods that "enrich, and not only reduce the object of study" [10].

Artistic work is effective in creating different poetic resonances for infrastructure, both in combination with site (for example in the Made of Walking residency project in Delphi) and by offering a different set of uses or practices for the infrastructure (as with *GPS Tarot*). This second point creates alternative textures through another facet

of infrastructural inversion. Bowker argues that blackboxing occurs when infrastructural developments become tacit, gaining an aura of inevitability, as if their development could not have taken any other course [11]. *GPS Tarot* offers a radically different account of the development and use of GNSS infrastructures, thereby achieving an infrastructural inversion, not through calling attention to moments of breakdown, but by offering an alternative account of the development, symbolism and use of the infrastructure.

The two remaining research questions dovetail with a discussion of the effectiveness of poetic techniques and what kinds of knowledge they can produce. In order to answer them, I consider my findings as a whole, giving an account of the wider metaphors produced both by participants in the research workshop and by myself in the artistic projects. In doing this, I consider what understandings emerged around the centrality of the user and the nature of more-than-human networks, at the same time drawing out their successes and shortcomings.

7.2.2 Shifting Understandings

- Does this way of shifting attention towards infrastructure:
  - Change understandings around the centrality of the user and user experience
  - Change understandings about the nature of more-than-human networks

In addressing these research questions, both the walking and design methods sought to create theoretical knowledge by destabilising existing understandings of GNSS and allowing alternatives to emerge in its place. The first method shifted the practices of the participant as a user of GNSS, the second method proposed scenarios with alternative GNSS systems. Here, the use of poetics draws on existing design approaches that seek to make the familiar unusual. Bell et al use defamiliarization as a tactic to help designers reflect on the amassing of inscriptions about which they may otherwise fail to be aware [12]. Chalmers and Galani propose looking at moments of breakdown in a new light, as

something that makes the technical tool visible, and thereby inspires new designs [13]. My own use of poetics, while inspired by these approaches, goes further. In concentrating on ontology, it interrogates the emergence of a technology, understood as an object or actor, in relation to surrounding elements in a sociotechnical assemblage. It is intended to question not just how a technology may be designed or re-designed, but also how it acts in the world and how that action re-draws its boundaries.

In addressing these ontological issues, my methods asked how understandings shift if the user is no longer foregrounded. Throughout the design workshops, on one level, the human user did became less important. In its place, participants proposed speculative satellite systems that held new ways of interacting with the world. These systems meant that, while the human at large was less central, the user as a figure did not vanish. Rather, through a strong focus on infrastructure, different types of metaphorical users emerged. These metaphors were sites of negotiation between human and machine concerns. These new combinations begin to point to understandings of 'more-than-human' networks. Building on the complexity, instability and multiplicity of these formations of 'user', I argue for a shift in understanding the relationship between user and infrastructure. Rather than proposing intersecting 'objects', 'networks' or 'structures', I follow one participant in emphasising a "field of signals" as a way of approaching the complexity of agential intra-actions. This metaphor, at once environmental and ambient, provides a useful conceptual base on which to build understandings of the actions of users, bodies, communications technologies, buildings and contextual scenarios. The fluidity and dynamism of the "field of signals" concept brings forward a different understanding about the centrality of user experience. It becomes another node in a topography of interacting elements, although one with different levels of importance, as understood through the different workshops, prompts and methods. This line of thinking also marks a shift in participants attention towards more-than-human networks, where the nature of user-ship begins to incorporate other non-human facets.

7.2.2.1 User

In its basic form, the user is understood as an agent that operates or interacts with something, typically a machine, network or service. Users are typically taken to be people. Indeed, several generations of HCI research have argued for a greater focus on the user as a person rather than a set of inputs and responses. Participatory approaches [14–16] emphasise the importance of incorporating peoples' broader needs and perspectives at every stage of the design process. This positioning works in a complementary way to the Weiserian focus on task rather than tool, where the person is interested (or understood to be interested) in performing a task rather than understanding the tool at hand [4, 5]. The aim of situating the user in a wider, human-centred design context is to allow tasks to be identified and executed more successfully (more efficiently, with greater satisfaction). The task, howsoever that is understood, remains the key factor in the creation of practices of design and use.

In the literature review, I explored the concept of inscription [17] to understand how users are created through the design process. Here, the figure of the user is understood through how affordances are set. Although a process of translation [18] means the person performing the task is not without agency, the terms of that agency are set by the design process [19]. The most common GNSS-driven task, based on the discussions that took place with participants, is personal navigation. Participants spoke about when, where and how they use GNSS, as well as whether it makes navigation easier or adds another confusing layer. Through the workshop process, an inscription that casts the GNSS user as a navigator remained a durable point of reference for participants, although possibilities for that behaviour to be negotiated (or translated [18]) according to context also exist. For example, one discussion focused on how using GNSS makes you present yourself to the world around you. Here, a participant from Brazil said that, where she was from, using locative services in the street made you appear as a tourist and therefore a target of robbery. In her experience, Brazilians who wanted to use GNSS to navigate would step off the street and into a shop to check their route before moving on.

From this example we can see that the 'user' can act as a site for performance or negotiation of surrounding contexts. On a grander scale, it has been proposed that the 'user' as a figure operates as a site for the advancement of specific interests and narratives. Wilkie and Michael offer an analysis of UK think tank Demos' work around location-based mobile phone technologies. Here, existing and future 'users' are understood as narrative agents that combine the social and technological to justify and advance preferred policy positions [20]. In this way, through their formation as actors who perform tasks, users can bring certain sets of interests into being through enactment and performance. In Wilkie and Michael's work, the user is a site of the emergence of policy because of the types of task they are understood to perform.

In my own research, I worked to provoke a re-consideration of existing performances undertaken by users and, thereby, question the narratives with which they are embroiled. In the walking workshops, an alternative user experience was created as a critical prompt through which to question everyday practices. Perhaps the strongest response to this modified experience came around the theme of privacy. Here, participants re-considered the "privacy calculus" which led them to exchange their personal information for the convenience of using GNSS navigation. In doing this, they were questioning the role of the user as it had been inscribed for them. They felt the benefits that convenient navigation brought them, but, inspired by the method, reflected on what they were giving up by using those services. In this way, the workshop challenged the narratives and power relations that are performed by the 'navigator' inscription and, while the workshop acted as a recalibration of user practices, the ontological positioning of the user remained intact. In other words, the user's agency continues to depend on how many systematic affordances they assent to, where the terms of the exchange remain out of the user's hands. While alternative practices, particularly new forms of mapping, were proposed, the importance of interaction or of 'using' a service continued to define the user even as the workshop encouraged participants to explore and shift the power relations created by those acts of use.

The strength of the user as an ontological inscription continued into the second method. In the designers' workshop, the 'silverheads' project expressly proposed this idea of withholding use as a form of agency. In the developmental design workshop, two groups took the prompt as a call to find alternative ways to maintain existing modes of use in the face of a political power shift (through hacking the GNSS infrastructure using bees and using magnetic crystals as an alternative navigation tool).

So, despite my efforts to subvert it, for some participants at least, the 'user' as constructed through existing practices remained difficult to de-centre and continued to be highly significant in defining future practices of use. However, although the user remained a significant point of attention, a shift did take place. Through an increased attention on the terms of use and what performances use enables, the relationality of the user was emphasised. The idea of the user as a relational figure is described by Hyysalo and Johnson:

> "The user refers to a relation, not to subjects or features of design space per se. It bridges between people out there and a rendition of them that is relevant for design. This is readily visible in reports and outcome briefings that designers, marketing departments and so on produce. The reports of "out there" reality are quite different from what anthropology, psychology, or sociology would produce of the same people." [21] (p. 74)

If we take it that the user is relational, then the question becomes about redrawing boundaries. Following Hyysalo and Johnson, this is likely to be born out of combinations of framings from designer, psychologist, sociologist and ethnographer and, I would suggest, the intentions and subjectivities of participants or users themselves. These expectations form a soft epistemological infrastructure alongside the affordances of the hard, technical infrastructure of ground stations, satellites and GNSS sensors.

7.2.2.2 Combinations

The combinations of human user and infrastructure that emerged from the speculative design workshops show how more-than-human networks can be posited and understood through the use of poetic methods. This is in addition to the infrastructural inversion work poetic methods undertake. The speculative design methods provide prompts to participants that elicit scenarios and objects that could exist in a future world. The participant responses are metaphors for the way GNSS is currently understood, eliciting concerns about their current use and alternative ontologies through which to change understands around more-than-human networks.

In one of the design workshops, when discussing the Group 2's project in which satellites form couples with each other and produce offspring, one participant asked: "Can satellites breed with humans?" It was offered as a joke, but, in fact, points to a complex question about combined and contested agencies. Satellites do breed with humans in the sense that their agencies are tightly overlapped and work to frame and produce each other.

In the design workshops, participants produced several examples of these speculative 'offspring'. They centred around themes of collaboration (GNSS-controlled agriculture) and contestation (surveillance and the refusal to be seen) between human users and infrastructure. Alongside these projects were ones that created human-satellite hybrids by having GNSS infrastructures engage with 'human' (or at least, earth-bound) problems such as preventing environmental collapse. In each combination, we can understand the meeting and enmeshing of the figures of user and infrastructure to create new sets of relations, agencies and motivations. Within these new sets of relations, the equation of user with human and infrastructure with material or machinic becomes less fixed.

In a recent book Benjamin Bratton offers a speculative reading of what he calls 'the Stack', an extensive meshwork of infrastructure, user, city and network. He charges this with explaining the way in which our evolving relationship with technology works

as a totality [22]. To do this, he draws on multiple examples from both the historical avant-garde and cutting edge technology. In the process, he offers a re-orientation of the term 'user' as something which does not necessarily equate with human, but can rather describe an actor (or combination of actors) which interact with a system. In this way, humans, animals or AIs can also be users. "Your mobile" he writes, "is not a phone anymore, it is more of a machine user" (p. 281). We can understand this point very clearly in relation to GNSS. The phone is an agent accessing a wider system, in our case, the GNSS infrastructure. Following Barad [7] and Haraway [23], the phone is not merely a machine user, but a hybrid or cyborg user, a combination of machine and human actions.

Considering Bratton's analysis alongside the outcomes of the design workshops lets us understand user-ship from several angles. In the design projects, when humans instruct GNSS to increase agricultural yield, they are acting as traditional users. However, when the satellites act to influence humans through branding in the 'time-o-poly' scenario or read social media feeds to understand who they will favour with better signals, they are also acting as users. In this case, however, the infrastructure they are using is a meshwork of human social relations. The satellite becomes the one accessing an interface and directing an infrastructure, turning humans into a tool through which to perform and actualise their judgments of the world. So, here, what we understand as the traditionally human role of 'user' is given to the infrastructure, and the 'infrastructure' role is given to a mass of traditional users. This inversion and re-orientation provides a way of thinking through possible futures, blending Weiser's task-focussed user with everything which surrounds it, until the task and the tool become synonymous, fluid and interchangeable.

7.2.2.3 Ambience

A fluid understanding of overlapping relations strongly harks back to a Baradian explanation of materiality. Here, objects (understood as apparatuses) emerge from combinations of overlapping agencies [24]. In much post-enlightenment philosophy, we are

used to understanding an action as something that comes from a causal agent, Barad proposes the opposite, suggesting that objects emerge from action. In the workshops, some participants described traditional causal boundaries between objects, where a more associative idea of causality might have been more appropriate. A good example is the idea of satellites as watchers that emerged during the walking workshops. When the GNSS network was described as "the all-seeing eye" or a participant drew sight lines with eyes coming down from the sky, they were using a familiar agential archetype to describe an emergent process. In keeping with an understanding of an infrastructure's texture [1], the metaphor of sight is a way of understanding the ways infrastructure acts. The metaphor, however, shifts the conceptualisation of the infrastructure. Because of the action of the infrastructure at large, the satellite is understood to be a metaphorical object that sees. The conceptual hybrids that emerge in this way are not false, but rather splinters or slithers of a wider picture or network.

This splintered and open understanding makes it difficult to orient theory around the agential power of a discreet object in philosophical [25], or design terms [26]. Following Barad, objects emerge from action as much as they act. I would describe this associative causality as a more ambient or environmental version of agency, something that is dynamic, shifting and all around, without always being visible. In this way, as a research method that develops and holds understandings of agency steady, poetic methods can also be understood as helping conceptual understandings emerge. Again, leveraging the idea of metaphor as a way of understanding the actions of infrastructure, participants described the walking workshops as "walking into signals", redrawing their surroundings as a "field" of overlapping waveforms in which the body and architecture are implicated as much as the devices we use to decode those signals.

This description is an apt way of describing the co-productive causality of overlapping agencies, a field from which different conceptualisations can emerge depending on how they are received and decoded in the same way a radio receiver forms meaning from the electromagnetic ether. The signal metaphor also points to a more avant-garde tradition

of art and design as seen in the projects described in Anthony Dunne's *Hertzian Tales* (2008), Mark Shepard's *Hertzian Rain* installation (2009) or the work of late 19th century radio pioneers such as Sir William Crookes who understood radio as an etheric realm of communication between hidden voices without bodies. In this realm even speaking to the dead might be possible [27] (p. 104 – 105). In such an ambient, but active realm, fluid, hidden, ethereal, action is sufficiently alienated from its object that cause and effect blend into one, each being a fluctuation of the field at large. The figure of the 'user' is not merely destabilised but irrelevant, replaced by a more ambient and all-encompassing understanding of agency.

This idea of ambience or signal realm can act as a metaphor to help us conceptualise more-than-human networks. In such a space we find a variety of signals, both active and hidden, it is an otherworldly space layered on top of our immediate surroundings. In this realm, the reception of and meaning created from electromagnetic signals can vary according to the other objects in the space and the nature of the receiver. The metaphor harks back to the radio signal realm described in the *Dial Stories* installation in the prologue to this thesis. This kind of realm is fundamentally emergent. By this I mean that signals appear and disappear, moving to the foreground and then falling back into the surrounding static. These fluctuations in signal are the result of a complex combination of factors, from the positioning of the user to the presence and action of surrounding objects. In this way, a message or a meaning can only emerge through a momentary more-than-human orientation of body, practice, infrastructure and surroundings. The idea of a field of signals is, therefore, perhaps the most successful metaphor to come out of the workshops in interrogating and shifting ontological understandings of user and infrastructure.

7.2.3 Summary

The two poetic methods I have used in this work exhibit different strengths. They work towards a similar goal; to explore infrastructural texture by using poetic staging,

metaphor and fiction, but a comparison is useful to understand their relative merits and applicability. Table 7-B presents a summary of their outcomes.

	Walking Method	Design Method	Art Practice
Infrastructural Inversion	Effective in achieving awareness of satellite infrastructure and electromagnetic signals.	Provided a broad awareness of infrastructure, but less of a sense of its technical operation.	Brought awareness of the infrastructure and offered alternative histories and contexts.
Shifting Ontological Understandings	Achieved some powerful shifts regarding the signal realm, decentralising the user and human. However, many responses engaged primarily with user-led practices.	The user remained a powerful arbiter of meaning, but multiple scenarios offered an increased awareness of infrastructural agency.	The ontological positions of user and infrastructure remained largely the same, but the site and nature of their interaction radically shifted.
Accessing Texture through Metaphor	A strong infrastructural inversion here brought powerful reflections on sociotechnical practices particularly in relation to privacy.	The way the infrastructure is felt was stated strongly here with themes of support, power, judgment and profit-making.	Existing texture was less important here than the proposition of a radically different set of uses and textures.

Table 7-B: Comparison of outcomes between poetic methods.

Infrastructural inversion was felt particularly strongly in the walking method, this is likely because of the immediacy and responsiveness of *GPS Test* in relation to the device's surroundings. This inversion laid the groundwork for a successful ontological shift experienced by some participants in focussing on the 'signals realm' rather than a user-centered realm that privileges their practices. In fact, I consider the 'field of signals' metaphor to be the most successful produced in shifting understandings about the centrality of the user and the presence of more-than-human networks.

In comparison, the design method produced more abstract outcomes. This is likely because participants were asked to think more conceptually about the infrastructure rather than engage with it on an empirical level. Nevertheless an infrastructural inversion was achieved to the extent that participants were able to reflect on the existing and potential actions of the infrastructure. The shift in ontological understandings was more subtle than I expected. Participants proposed scenarios that continued to be driven by the user, or the human, at least as much as by the infrastructure. The infrastructure's actions were understood in relation to humans in the majority of cases. Only Group 2's scenario offered a satellite infrastructure which was interested in its own culture and survival rather than life on earth. I would suggest that the familiarity of the design workshop as a user-centered design technique contributed in part to this outcome. The textures described by the scenarios were, however, very rich. These included GNSS infrastructure's role in supporting other practices, producing wealth and profit and engaging with strong themes of tracking, power and judgment.

The art practice manifestation of my methods held slightly different aims from the other two methods. While it certainly brought a strong awareness of the presence of GNSS infrastructure, it was less concerned with providing a diagnosis of existing textures and more concerned with offering an alternative texture which asked participants to rethink their practices. In this way, while it can be said to provide a shift in the site and nature of sociotechnical practices involving GNSS. The interaction between these two no-longer took place in terms of discreet interactions around established practices, but instead as part of a wider ecosystem of signs and stories.

To conclude, the walking method was perhaps most effective at providing a radical shift in understandings. This is likely because it was hands-on and worked to invert not just an understanding of infrastructure but the everyday task of navigation. The design workshop was partially successful, but, because it worked more conceptually and because it used a more familiar 'design' technique, it would, I suggest, require repeated sessions to build a radical ontological shift. That said, considering this was a short,

one-off session, the results were promising. The art practice was more of a personal response to the research questions rather than a concerted effort to pose those questions to participants, however, it has been successful in achieving a shift in understandings around the way GNSS satellites are narrativised and the possible practices they could support.

7.3 Innovations

The innovations described here engage with what Salter et al identify as the potential for art practice to contribute to research by engaging with method [3]. Through this attention to method they contribute to STS and STS-influenced ethnographies by arguing for the usefulness of poetic methods. As part of an empirical study, poetic methods can act as a way to manifest infrastructural inversion and achieve a rich examination of infrastructural texture through a concentration on the use of metaphor. The work also seeks to engage with HCI debates around critical and speculative design by offering an engaged, critical, participant-facing method with avant-garde and ontological concerns.

7.3.1 In relation to STS

Poetic techniques contribute to method in STS and STS-influenced ethnography in a number of ways. Firstly, an attention to research staging can allow the researcher to design experiments which can re-frame an existing technology or set of practices. This re-framing can act as a way of working through blackboxing and design inscriptions that may not be clear to participants. This was achieved in both techniques described in this thesis. In the walking method participants attention was drawn to satellites which were "being located by us, rather than the other way round" in a way that "brings it home... that they're really up there". In the design method, participants developed several strong metaphors which drew attention to the existence and action of satellite infrastructure.

These methods can also, to some extent, work towards the emergence of alternative ontological understandings of a technology or practice, framing them within a broader, more-than-human assemblage. Although existing ontologies such as the 'user' remained persistent for some participants, a shift was achieved for others. This was evidenced in the thesis through the development of the "field of signals" concept which shifted GNSS interactions from being understood as between discreet causal entities to being a series of overlapping actions understood in a more environmental sense. In addition, art practices, such as the *GPS Tarot* project can also work as a continuation of these re-framings, taking the critical work further and developing more elaborate re-framings for a wider audience.

Such approaches also contribute to a broader understanding of the kind of data produced by participants. By focussing on emergent metaphor as a way of accessing texture, poetic techniques allow more fleeting, richer and less-fixed feedback from participants, encouraging them to join with researchers in, in John Law's words, "mak[ing] realities and hold[ing] them steady for a moment against a background of flux and indeterminacy" [9] (p. 10). Poetic methods do not aim to be a complete methodological solution, but rather a set of tactics, to be used in combination with other techniques where they can, in Lury and Wakeford's words offer "answerability" [28] a research project that addresses tacit actors and implicit concerns.

Poetic methods seek to use forms of staging borrowed from art practice to critically re-frame existing understandings of a technology or practice. The aim of this re-framing is to catalyse the process of participant reflection. This catalysation process should be undertaken carefully to avoid participants repeating back the terms that go into the staging of the experiment. However, done correctly it can invite participants to go deeper into a consideration of their own practices by re-framing them and the way they relate to a wider sociomaterial assemblage. The idea of catalysing participant reflection is not completely new, and here I build on ethnographic walking methods [29–31], which stage participant interviews as walks through sites relevant to the area of interest. In

ethnographic terms, walking has been understood as "an intrinsically social activity" [32] (p.43) through a person's conscious and unconscious interactions with the other people around them. By staging research in a way that foregrounds infrastructure, I turn this intrinsically social activity into a sociotechnical activity.

At this point, it is worth mentioning what could be offered as a counter argument; that through the extensive staging of the experiments, poetic methods begin by describing what they seek to study. Rather than generating new knowledge, they are restating their starting position and using participants as props or accomplices to this end. In response I would say that poetic methods certainly do seek to intervene in participants' understandings, but by working as a catalyst for surrounding concerns, rather than overfitting the question to the response. The interventions poetic methods make should be understood as moments of impact that are then traceable through the ripples they send out. By seeing where these interventions travel and what other elements they come into contact with, they glean new knowledge of their sociomaterial surroundings, at the same time leaving space for alternative framings, configurations and ontologies.

Indeed, in the work described in this thesis, several alternative ontologies for GNSS were able to emerge. In the workshops, participants described satellites as "guardian angels", "companions" and an "all seeing eye". A heavy use of metaphor was intrinsic to this process and also allowed the development of the "field of signals" concept to describe emergent intra-actions.

In terms of the methods' transferability, it is worth noting that a radical shift away from the centrality of the user was difficult to achieve consistently within the design workshops. This may have been an effect of the form and staging of the experiment, building on a workshop model often deployed in user-facing research and used by the professional designers who formed the second participant cohort. It may also be down to the short duration (around two hours) of the research workshop. It may well be too much to ask participants to radically shift a lifetime's use of interfaces and understanding of ontology in one session. In comparison, the walking studies achieved a similar

defamiliarisation from the leveraging of typical sociotechnical practices, as opposed the familiar design workshop format. The use of poetic techniques to access the ontological emergence of more-than-human networks, may then require more innovative staging, extended sessions of multiple workshops or a deeper overlap with art practice. We can see the effects of a stronger deployment of art practice in the *GPS Tarot* project. This project presented participants with a more developed alternative mythology for GNSS satellites.

Again, in terms of transferability, I do not suggest poetic methods can or should be used as an off-the-shelf approach, rather they should be a modular element within a wider research and / or art approach. As part of a suite of other research tools, they have considerable power to leverage metaphor as a way of generating knowledge and inspiration. For ethnographers, they can achieve infrastructural inversion, re-frame hidden or ontologically obscure elements of an assemblage and catalyse participant reflection. In order to achieve successful poetic methods, I would encourage researchers, where possible, to collaborate deeply with artists to develop methodologies and experiments. Artists, especially those with participatory or installation-based practices, have considerable experience in creating environments and interactions that require people to question their assumptions about art, space, engagement and process.

To conclude, the key takeaway for STS researchers interested in building on the work contained here is the power of symbol and metaphor in framing research or art production and reading emergent data. This offers a new way to help participants access blackboxed or ontologically obscure research topics.

7.3.2 In Relation to HCI

For designers and design researchers, poetic methods can provide an engaged tool with which to approach more philosophical questions about the nature of technologies and the ways they act. Within the existing literature, this attention to ontological issues

cuts a path between more applied understandings of speculative design [33, 34] and formulations which have been accused of being elitist because of their orientation in an gallery-facing, avant-garde tradition [35] (p. 290). My approach is participant-facing and engaged in pedagogic as well as research-driven concerns. In this engagement, it finds kin with the participatory approaches proposed by Forlano and Matthew [34]. At the same time, through its commitment to ontological exploration it maintains the "reimagining" of both reality and our relationship to reality suggested by Dunne and Raby [36] (p. 161). Poetics, and in particular, metaphor is used as a bridge to access infrastructural concerns that are either tacit and hidden or ontologically obscure. In this way, poetic methods can maintain the public facing, engaged drive of participatory work with the desire to question the formation and operation of more-than-human networks.

While this formulation does not seek to contribute to what critical design is or isn't, it does give a clear use case of participant-facing work with an ontological bent, one that follows Forlano and Matthew [34] in seeking to apply the work through use with participant groups, but maintain the transformative, philosophical concerns cited by Dunne and Raby [36].

Besides this contribution, poetic methods can also be said to work through some other points raised in the early chapters of this thesis by offering a route to navigate some terms of the relationship between STS, HCI and design. In the methods chapter I described Tom Jenkins' assertion that ANT-influenced approaches can only "analyze networks that already exist" and are not "well equipped for conceptualizing and generating networks (or products or services) that do not yet exist" [26] (P.829). Even though the participatory workshops may have been largely diagnostic rather than concerned with producing new products or services, *GPS Tarot* can be said to have used these techniques to generate a new network and service (albeit one unlikely to achieve mass adoption). It was able to develop this outcome through an expanded ontological understanding of the existing and potential emergent relationships between user and infrastructure.

The work also brings an innovation to Ratto's critical making work [37, 38]. This

work shares many resonances with my own, through its positioning as "design-oriented-research" [39]. However, Ratto's work hinges on foregrounding the material and the act of making, frequently through the use of DIY electronics. My own work engages with materiality through its interest in infrastructures, but is more ambivalent about engaging with the material base of a technology directly. This is in part because the material infrastructure I work with is less immediate, being distributed around the planet and the mid-earth atmosphere. However the work is also primarily concerned with the role this material base plays as symbol. In this way it offers a more ephemeral, conceptual and poetic understanding of critical making. This understanding does not require direct engagement with the material, but rather engagement with a set of ideas of what that material is and how it is understood. Symbol and metaphor can therefore also act as a focus for what Ratto calls an "act of shared construction, joint conversation, and reflection"[37](p. 253).

7.4 Conclusions

In this thesis I have developed poetic methods to re-frame GNSS infrastructure and its influence on sociotechnical practices. I explored this relationship by constructing a walking method that had participants question their typical sociotechnical practices around GNSS. These practices were disrupted by methods that sought to reveal the presence and influence of GNSS infrastructure. As I discussed earlier in this chapter, it would be disingenuous to suggest that I made the infrastructure visible or removed the blackbox completely. Rather, the research technique produced an interpretive 'greybox' that depicted the infrastructure in a different light. I argue that this kind of re-framing is a typical and necessary part of research design and it can be used to great effect to catalyse participants' reflection. In designing such techniques, I argue that researchers should be aware of both the contexts that form around their research and the contexts that their research informs. They should also introduce answerability into the research

method. By this I mean, the method should be iterated until it can address the question, although it need not create a falsifiable answer. Instead it is reasonable to see research as an activity that forms different realities around the object of study.

The framings which emerge from these also feed into my use of artistic practice to create new mythologies for GNSS. These extended metaphors represent a different form of poetic methods, one that is centred on individual practice. As such, the artistic practice element of the work is difficult to understand as an off-the-shelf research method. This is also true of the innovations I offer for STS and HCI researchers. What poetic methods do offer is a strong call for the power of symbol and metaphor in staging research and understanding how people interact with infrastructures.

7.4.1 Further Refinements and Future Work

Based on my experiences here I can offer several suggestions for further refinements of a poetic methods approach. The participant facing workshops here were all conducted in short time-frames, typically in sessions that were between two and three hours long. The advantage of this approach was its accessibility. Short sessions require less time commitment from participants. Indeed, over the course of the work, two attempts to organise day-long workshops drew such a low number of sign-ups that they had to be abandoned. However, in future, I think the approach would benefit from working with participants over a series of sessions, allowing participants to develop deeper understandings of both the technical details of the infrastructure and the potential of the technique. The benefits of a deeper, more time-consuming approach can be seen in the art projects described here. This alternative workshop or workshop series may be closer in form to a taught course than a participant study and care and consideration will therefore have to be given to the context in which it is offered, which participants it is offered to, and perhaps a more clear statement of the relationship between research and pedagogy in such a situation. Once the technique becomes a series of sessions, or a working group, it takes on a different set of contexts and commitments. This will, of course, also have to

be reflected in any analysis done on the data which emerges from the sessions.

Despite these complications, the idea of more committed or repeated sessions holds considerable promise, especially in grappling with more ontologically obscure areas of research. For example, extended and repeated sessions which take diverse and less familiar forms would allow participants more time to engage with ideas of more-than-human networks, what they are formed of, how their effects can be felt and how they could be represented in mock-ups and artefacts.

Since completing this work, I have been using similar techniques to explore issues around artificial intelligence and machine learning. In a similar workshop / art installation model, I have run projects at Zaratan Gallery Lisbon and Antiuniversity Now in London. My experiences in this project have been similar in the sense that work driven by artistic practice is an effective extension and deepening of themes around more-than-human networks. I therefore am encouraged to continue developing poetic methods, with a particular interest in creating more and continued participant engagement and more realised artistic outputs.

A grand guiding aim for this ongoing project is to explore ways to provide speculative ethnographies of more-than-human networks. Poetics has a way of embracing the contingent and ontologically obscure that can provide new understandings of the types of existence and action these networks hold. While this definition of ethnography may indeed be stretching it beyond the shapes in which it is understood in the academy, based on my work here, art practice can provide a flexible and effective way into depicting, understanding and critiquing the rhythms and textures of more-than-human networks. This work can create resonance and sympathy across these networks, perhaps best displayed in the emergent metaphor of the GNSS satellite as a "companion". Eventually, I hope that a greater openness to understanding the actions of these networks can create a willingness to understand them in terms that do not centre or privilege the user or the human.

The use of poetic methods in these and other forums is ongoing and will no doubt be further iterated and refined as it develops across different art and research contexts.

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Appendix A

A.1 Publications

- Christopher Wood, Stefan Poslad, Antonios Kaniadakis, and Jennifer Gabrys. 2017. What Lies Above: Alternative User Experiences Produced Through Focussing Attention on GNSS Infrastructure. In *Proceedings of the 2017 Conference on Designing Interactive Systems (DIS '17)* https://doi.org/10.1145/3064663.3064757 (**Best Paper Award**)

- Christopher Wood, Stefan Poslad, Jennifer Gabrys, and Antonios Kaniadakis. 2017. GPS Tarot: Encounters with Satellites as Divination Tools. In *Proceedings of the 2017 ACM Conference Companion Publication on Designing Interactive Systems (DIS '17 Companion).* https://doi.org/10.1145/3064857.3079186

- Christopher Wood. 2017. GPS Tarot. In *Critical Kits and How We Use Them* edited by Neil Winterburn and Hwa Young Jung. Liverpool: Torque. 39-41.

- Christopher Wood, Stefan Poslad, Jennifer Gabrys, and Antonios Kaniadakis. 2016. Dial Stories: The hybridisation of site using radio as a locative technology, In *Proceedings of 4th Conference on Computation, Communication, Aesthetics & X (xCoAx)*, 7-8 July 2016, Bergamo, Italy.

- Christopher Wood. 2016. Edges of Location: Infrastructures and Practices of

Locative Media in the City. In: S. Sparke & G. Cairns (eds.), *AMPS Conference Publication Series 6. Digital Cultural Ecology and the Medium Sized City.* University of the West of England, Bristol, 21 22 April 2016. pp.16-24

A.2 Conferences

- Christopher Wood. 2017. Exploring the Intersection of Spatial Practices and Technology with Critical and Creative Methods: Some Experiences and Suggestions. sIREN Arts and Digital Practices. Edinburgh College of Art. 31 May 2017.
- Christopher Wood. 2017. Critical Reflection and Affective Experience in the Making Visible of GNSS Infrastructure. Sensor Publics: The Politics of Sensing and Data Infrastructures. Munich Technical University (TUM). 7 April 2017.
- Christopher Wood, Stefan Poslad, Jennifer Gabrys, and Antonios Kaniadakis. 2016. Studying digital locative infrastructures: a reflective workshop approach, Pre-ICIS workshop, International Conference on Information Systems (ICIS) 2016, Dublin, 10 December, 2016.
- Christopher Wood. GPS Tarot. 2016. Critical-Kits: Art, Technology & Distributed Participation. Re-Dock, Liverpool, 30 November 2016.
- Sensing, Walking and Embodiment With and By Technologies [track convener] 4S/EASST, Barcelona. 31 August to 3 September 2016.

A.3 Exhibitions

- GPS Tarot. Electromagnetic Field Camp. August 2018.
- GPS Tarot. Zaratan Arte Contemporanea, Lisbon. April 2018.

- GPS Tarot. Intersections. Mile End Art Pavilion, London. September 2017.
- GPS Tarot. FACT Liverpool. July 2017.
- Walking With Satellites. Project Anywhere (peer-reviewed exhibition programme). 2016-2017. Available at http://www.projectanywhere.net/.
- Walking With Satellites. Sound Development City. Madrid to Casablanca. September 2016.
- Spatial Machines. Loitering With Intent. Manchester Peoples' History Museum. August 2016.
- Walking With Satellites. Made of Walking. Delphi, Greece. July 2016.